

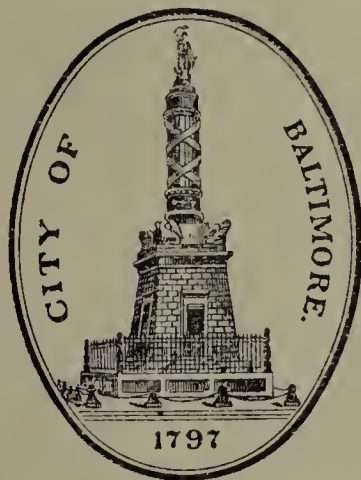
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REPORT
OF THE
SEWERAGE COMMISSION
OF THE
CITY OF BALTIMORE

CONSISTING OF
MENDES COHEN
F. H. HAMBLETON
E. L. BARTLETT

APPOINTED BY
JOINT RESOLUTION OF THE CITY COUNCIL

APPROVED 25TH MAY, 1893



BALTIMORE

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REPORT

OF THE

SEWERAGE COMMISSION.

To the Honorable, the Mayor and City Council of Baltimore:

The Sewerage Commission has the honor to submit a full report of its investigations and recommendations in regard to the sewerage of the City of Baltimore.

The Commission was appointed under Resolution No. 189 of Session 1892-93, as follows:

“Resolution authorizing the Mayor to appoint a commission, composed of three persons, to examine into a more perfect system of sewerage for the City of Baltimore.

“*Whereas*, The adoption of some scientific system of sewerage in this city has long been recognized as a necessity, and public interest has of late been awakened as to this and other sanitary precautions by the adoption of National Quarantine regulations on account of epidemics in other countries, and the necessity of providing against their outbreak here, and we believe that some effective action should be secured while public interest is aroused to the importance of the question;

“*Resolved*, That the Mayor be, and he is hereby authorized and directed to appoint a commission, to be composed of three persons, who shall examine into the necessity for a more perfect system of sewerage for the City of Baltimore, and report the result of their investigations to the City Council of Baltimore at its adjourned session, together with their recommendations as to the system to be adopted and the mode of carrying the same into effect; the said commission to act without compensation.”

“Approved May 25th, 1893.”

“FERDINAND C. LATROBE, *Mayor*.”

Under this resolution the Mayor appointed as the commission Messrs. Mendes Cohen, F. H. Hambleton and Henry T. Douglas.

The Commission organized on the 19th July following, by electing Mr. Mendes Cohen, chairman, and Mr. H. T. Douglas as secretary *pro tem*.

On the 26th September of the same year it so far complied with that portion of the resolution creating it, as required it to report to the adjourned session of the City Council.

In its report of that date to the Mayor and City Council, it stated "that, in its judgment, a thorough system of sewerage is an absolute necessity for the city, and that measures to effect it ought not to be longer delayed."

The report enlarged upon the conditions and information necessarily precedent to any determination of the proper system upon which the sewerage should be effected, and called attention to the entire omission of any appropriation to meet the necessary cost of investigations.

An appropriation was subsequently made, under Resolution No. 212 of same session, as follows:

"Resolution appropriating a sum of money to meet the expenses of the Commission on Sewerage.

"*Resolved by the Mayor and City Council of Baltimore*, That the sum of five thousand dollars, or so much thereof as is necessary, be, and the same is hereby appropriated, to meet the expenditure required by the Commission appointed under the provisions of a joint resolution of the Mayor and City Council of Baltimore, approved May 25th, 1893, authorizing the appointment of a commission to examine into the necessity for a more perfect system of sewerage for the City of Baltimore.

"*Resolved*, That all bills presented by the Commission under the resolution shall be first approved by the President or Acting President of the Commission, with his signature, and then, after approval by the Mayor, be presented to the Comptroller, who shall draw his warrant for payment thereof on the City Register; the amounts to the extent of the appropriation to be paid from any money not otherwise appropriated in the City Treasury."

"Approved October 14th, 1893."

"FERDINAND C. LATROBE, *Mayor*."

On 19th October, 1893, the Commission organized for work by the securing of office and working rooms in the Equitable Building.

The first preliminary to the operations of the Commission was deemed to be a relief map of the city, on a scale to make possible a study of its drainage areas.

For the construction of such a map, the city was found to possess no adequate data. In fact, a general topographical survey of the city had only just been undertaken, and its results might not be available for the purposes of this Commission without a very long and undesirable delay.

To save time, the Commission was glad to avail itself of the use of contour maps of the city and its environs prepared for the use of the Corps of Engineers, U. S. A., during the late war, which Colonel Wm. P. Craighill, Corps of Engineers, the officer then in charge of this district, now Brigadier-General and late Chief of Engineers, was so obliging as to place temporarily at our service.

With this aid our preliminary studies were effected; but the determination of many questions involved in the conclusions of this report, has required the more precise data obtainable only as the topographical survey progressed.

Reports of progress were made to the Mayor and City Council under date of January 10th, 1894, and January 2d, 1895. The latter report showed a total expenditure to December 31st, 1894, of \$3,231.97, principally for office work in the collection of data and the making of maps. It stated:

"It has been thought desirable by your Honor, and was probably intended by the Joint Resolution appointing the Commission that its final report, recommending the system to be adopted, should be accompanied by an approximate estimate of the cost of carrying the same into execution."

* * * "To pay for the services of consulting engineers and to meet the expense of a detailed investigation of their plan to be recommended with a view to an estimate of its cost the Commission deems it necessary that a further appropriation of twenty thousand dollars be placed at its disposal."

This requirement was met by Ordinance No. 25 of the Session of 1894-95.

"An Ordinance appropriating a sum of money to meet the expenses of the Commission on Sewerage.

“Section 1. Be it enacted and ordained by the Mayor and City Council of Baltimore, That in addition to the unexpended balance of one thousand seven hundred and sixty-eight dollars and three cents of the five thousand dollars appropriated under resolution approved October 14, 1893, the sum of twenty thousand dollars, or so much thereof as is necessary, be and the same is hereby appropriated to meet the expenditures required by the Commission appointed under the provisions of a joint resolution of the Mayor and City Council of Baltimore, approved May 25, 1893, authorizing the appointment of a Commission to examine into the necessity for a more perfect system of sewerage for the City of Baltimore.

“Section 2. Be it enacted and ordained, That all bills presented by the Commission under this ordinance shall be first approved by the President or Acting President of the Commission with signature, and then, after approval by the Mayor, be presented to the Comptroller, who shall draw his warrant for the payment thereof on the City Register; the amount to the extent of the appropriation to be paid from any money not otherwise appropriated in the City Treasury.”

“Approved March 29, 1895.”

“FERDINAND C. LATROBE, *Mayor*.”

With the aid of this further appropriation the services of consulting engineers were engaged, necessary surveys were made and the investigations generally continued.

Further annual reports of progress have been made on January 6th, 1896, and January 12th, 1897.

On May 22d, 1896, Col. Douglas announced, to the regret of his colleagues, that, owing to the pressure of professional engagements upon his time, he had that day forwarded to the Mayor his resignation as a member of the Sewerage Commission.

On July 25th, following, the Mayor appointed Mr. Edward L. Bartlett to fill the vacancy on the Commission.

On July 27th, 1896, Mr. Bartlett met with the Commission, and, Mr. Cohen having resigned the chairmanship, the Commission was reorganized by Mr. Cohen's re-election to the chair, and as thus constituted, it has since continued its work.

The surveys required by the consulting engineers for an investigation of a possible sewage outfall in Anne Arundel county, together with the maps and plans to elucidate it, were completed and forwarded to those gentlemen in August, 1896.

Numerous test pits were sunk to demonstrate the character of the soil available for filtration of the sewage in Anne Arundel county, and samples thereof were secured and arranged in the office for reference.

An expert was also employed to ascertain and report the value of the land probably required for filtration purposes.

On November 30th, the text of the joint report of the consulting engineers was received and a few weeks later the maps and plans to illustrate it were in hand.

Since then your Commission has been diligently engaged in discussing the several plans, the result of its labors being now submitted.

THE WORK OF THE COMMISSION.

An investigation and determination of a plan for a sewerage system requires, in addition to a topographical plat of the area to be sewerred, similar plats of such adjacent districts as may be traversed by the outfall sewers, or otherwise made use of in the final disposal of the sewage.

A knowledge is also required of the geological formation of the areas under consideration, in order to estimate the character of the material to be traversed by the various sewers, both for collection and discharge, and more particularly for the purpose of determining in regard to the feasibility of disposing of the sewage through filtration upon land.

It is with pleasure that the Commission here records its sense of the assistance rendered to it in this branch of the investigation by Professor Wm. Bullock Clark, State Geologist of Maryland.

Besides a personal examination of localities in company with the Commission and its engineers, Professor Clark further aided the Commission by facilitating, through his official co-operation, the survey and other examination of lands thought suitable for the outfall of the sewage, and has supplied our Consulting Engineer, Mr. Hering, with a condensed summary of the features characteristic of the region.

This description of the geology of Baltimore and the adjacent region accompanies this Report as an appendix to the Report of the Consulting Engineers.

The next consideration, and the first question to be determined in the general discussion of the subject, is as to whether the system shall be *Combined* or *Separate*.

A *Combined System* is understood to mean the disposal through one set of sewers of the storm water falling upon the streets, house-tops and open spaces of the area under consideration, together with all the water-borne domestic waste, and more or less of that from manufacturing establishments.

A *Separate System* is understood to mean one in which storm water is excluded from the sewers devoted to house drainage, and is otherwise disposed of.

The solution of this question depends upon various considerations, all of which need not be enumerated here.

It will be sufficient to say that your Commission has been advised and has concluded, that the interests of the City of Baltimore will be best served by adopting the separate system, because:

First. The City has already constructed some thirty-three miles of sewers or drains for carrying off storm water at a cost of not far from \$4,000,000. These discharge directly or indirectly, and usually by the most direct lines, into the harbor, and either answer, or can be made to answer, the purposes of their construction.

Second. These sewers, which will hereafter in this Report be referred to as *Drains* or as *Storm-water Drains*, were not designed for carrying domestic sewage, are not adapted to such purpose, and even if they were, the discharge of domestic sewage into the harbor is undesirable for reasons which will be given later on.

Assuming then, that the separate system is that to be adopted, we must next ascertain the volume of sewage which will accumulate daily, and which must therefore, each day, be transported to the outfall point. This volume is dependent, first, upon the population; second, upon the water supply, or rather, upon the total water consumption of the entire population; and, third, upon the amount of storm or ground water which will find access to this separate system, not-

withstanding the fact that the bulk of the storm water is carried off separately.

Having ascertained the volume of sewage to be provided for, the next question, and for the City of Baltimore, perhaps the most important question of all, is: What shall be done with it? And where and how shall it be discharged, so that the disposal shall be final, or, at any rate, such that no further inconvenience, not readily obviated if necessary, need be apprehended from it?

The elements and special conditions leading up to the determination of these questions will now be considered separately.

GENERAL FEATURES OF THE CITY WITH REFERENCE TO ITS SEWERAGE.

The City of Baltimore includes within its present boundaries some thirty-two square miles of surface having an extreme breadth from north to south of six miles, and from east to west of about six and one-fourth miles. Of this total, the paved and built-up portion of the city may be estimated at eight square miles; the partially built-up or suburban portion at five square miles; the rural portion, including 1,137 acres of public parks, at sixteen and a half square miles, and the water area at about two and a half square miles.*

About one-half of its southern boundary is formed by the tidewaters of Patapsco River affording a harbor with upwards of twelve miles of water frontage. The land rises gradually from the flat ground surrounding the water front to an extreme height of 460 feet at the northwest corner of the city, and is intersected by numerous lines of natural drainage to the harbor. Of these, the most important is Jones' Falls, which traverses the center of the city in a general direction south by east, and having at the northern boundary an elevation above tide of about 160 feet.

This stream, where it flows through the built-up portion of the city, say for one-half its course within the city limits, has its open channel confined between walls of masonry at a width of from sixty feet to one hundred feet. It has hitherto afforded the most available means of draining the

* Report of the Topographical Survey of Baltimore for 1894.

districts tributary to it; and has for long years been a source of continued nuisance and expense, due to the collection of offensive matter in its open channel, to the necessity for keeping the channel unobstructed for the passage of floods, and to the difficulty of dredging it, which involves the use of special apparatus capable of passing under the numerous bridges.

Harford Run and Harris Creek to the eastward of Jones' Falls, and Chatsworth Run and Schroeder's Run to the westward of that stream have been arched over in past years, and are converted into storm-water drains.

Gwynn's Falls and its tributary, Gwynn's Run, are to the extreme west of the present built-up portion of the city. Their course is, for some three and a half or four miles, through the western and southwestern section of the city area.

The advancing growth of the city has not yet seriously affected the main stream, but Gwynn's Run already serves as the means of draining an extensive section, including numerous butchering establishments only recently brought within the city limits.

The Patapsco River, on which Baltimore is situated, is but a broad estuary or arm of the Chesapeake Bay for the 12 miles between the city and the bay, with so small a fresh water flow as to make no appreciable current, and with a mean rise and fall of tide which does not exceed sixteen inches.*

The winds are the most powerful agency affecting the regimen of the harbor. A heavy southeast wind raises the water some six feet above mean tide; whilst on the other hand, a strong northwester may drive the water out of the river, leaving it some five feet below the mean.

Under these conditions it will readily be seen that whatever solid matter is permitted to enter the harbor remains there, sinking to the bottom or floating on the surface as the case may be, but never getting far away from the point of entrance; so that sewage and other filth, if allowed to enter with storm water, are not in this way gotten rid of, but continue a source of nuisance and, after befouling the harbor and silting up the channels, the accumulating matter has to be removed in the end by dredging.

*See Coast Chart No. 136, U. S. Coast and Geodetic Survey.

For this reason, if for no other, it is evident that the discharge of sewage into the harbor should be avoided.

POPULATION.

By the United States Census of 1890, the population of the City of Baltimore, including that of the recently annexed portion of Baltimore county, is placed at 434,151.

By the Police Census of the year 1896, it appears to be 542,754, and by that of 1897, 556,717. By the estimates of the Health Department for July, 1896, it is given as 506,398. This Commission, however, from the best information available, believes it to be fairly estimated at 550,000. It is not, however, for the population of to-day only that the proposed system of sewerage is to be provided. Your Commission has not thought its duty would be properly met, if it estimated for less than the probable population at the end of the next thirty years; at which time, if the present ratio of increase continues, we believe the city will include not far from one million of people.

A consideration of the probabilities in this regard may be aided by reference to a diagram (Plate I) appended to this report.

WATER SUPPLY.

Baltimore is furnished with an abundant supply of good water from two sources.

First. Jones' Falls.—This stream, already described as passing through the heart of the city, afforded for many years the only distributed supply of drinking water. It was originally taken from the stream at a point between the present crossings of Preston street and Hoffman street; but has since been derived from an impounding reservoir on the same stream, at its confluence with Roland Run some three or four miles beyond the present city limits. It is thence brought into the several distributing reservoirs. The daily consumption from this source now amounts to nearly twelve million gallons.*

Second. Gunpowder Falls.—During the year 1881, works were completed, by which a supply from this stream was impounded at Loch Raven, about eleven miles from the

*Letter from Chief Engineer of Water Department, July, 1897.

centre of the city, thence led by an aqueduct in tunnel to different receiving and distributing reservoirs. From this source is derived a present daily consumption of nearly 40,000,000 gallons.

The daily consumption of water from both these sources now amounts to about 52,000,000 gallons, or about ninety-five gallons per head of present population.

For the disposal of this liberal supply after it has served its purpose of refreshing and cleansing over a half million of people and meeting their general demands, no provision has thus far been made. It finds its own way to the harbor, sometimes by way of the storm-water drains, but more generally by way of the street gutters, flooding the streets in the winter season when the gutters are obstructed by ice, and causing thereby much inconvenience and expense.

CLIMATIC CONDITIONS.

As sewage disposal in some of its methods, particularly in those of filtration and broad irrigation, is affected by temperature as well as by rainfall, it will be proper here to note the climatic conditions prevailing at Baltimore.

RAINFALL.

The meteorological statistics for the City of Baltimore have been accurately kept for but a few years past, so that the records, whilst furnishing information as to total precipitation, and enabling estimates to be made of the average fall to be expected and provided for, are not so explicit as to the amount of exceptionally heavy rainfall in short intervals of time. These data become important for properly estimating the capacity of the storm-water drains.

For example, a rainfall of two inches in twenty-four hours may be considered as large, and is not of very frequent occurrence, but when this amount or more falls in a single hour, as occasionally happens, it may overtax the capacity of drains not suitably designed for meeting such a downpour.

On September 6th, 1895, this city sustained a rainfall of $4\frac{3}{4}$ inches in $16\frac{1}{2}$ hours. Even this might have been carried off without trouble if the rate of fall had been uniform, but when, during this storm $1\frac{1}{2}$ inches fell in 2 hours, it proved to

be more than some of the drains were able to bear, and the result was the bursting of several of them.

For further example, on September 19th, 1896, ninety-five hundredths of an inch fell in fifteen minutes, or at a rate which, if continued for an hour, would have equalled three and eight-tenths inches in that time.

Appended to the special report on Storm-Water Drainage (Appendix B) will be found a tabular statement showing the extraordinary rainfalls in recent years.*

The annual rainfall is about an average of that found east of the Mississippi valley, being 43.85 inches, with extremes of 28.75 inches in 1819 and 62.04 inches in 1846.

In the following tables the mean precipitation and the mean temperature for each month are given, together with those of some other cities, with whose systems of sewage disposal it may be convenient hereafter to compare that to be recommended for Baltimore.

MEAN PRECIPITATION AT BALTIMORE COMPARED WITH THAT AT OTHER CITIES.†

INCHES.									
	Baltimore.	Worcester.	Boston.	Chicago.	Melbourne.	Berlin.	Dantzic.	Paris.	London (Greenwich).
Jan.	3.33	3.92	4.3	2.2	1.73	1.23	0.99	1.48	2.43
Feb.	3.50	3.23	3.6	2.3	1.76	1.47	0.78	0.87	1.70
Mar.	4.10	3.61	4.3	2.5	2.03	1.48	1.07	1.39	1.39
Apr.	3.43	3.91	3.7	3.1	2.38	1.60	1.00	1.47	1.95
May	3.78	4.14	3.4	3.6	2.15	2.01	1.72	2.07	1.84
June	4.02	3.29	3.4	3.6	2.03	2.42	2.04	2.13	2.14
July	4.70	3.76	3.5	3.7	1.90	3.45	2.54	2.15	2.49
Aug.	4.05	4.92	4.3	3.5	1.81	2.37	2.50	1.76	2.52
Sept.	3.88	3.61	3.0	2.8	2.33	1.62	1.59	1.90	2.49
Oct.	2.98	4.36	4.3	3.2	2.91	1.32	1.38	2.03	2.76
Nov.	3.03	4.04	4.6	2.7	2.50	1.77	1.66	1.44	2.03
Dec.	3.05	3.78	3.5	2.2	2.35	2.01	1.29	1.37	2.39
Annual	43.85	46.57	46.1	35.4	25.88	22.75	18.56	20.06	26.13

*See also Plate XI.

†Furnished by the U. S. Weather Bureau.

MEAN TEMPERATURES AT BALTIMORE COMPARED
WITH THAT AT OTHER CITIES.*

DEGREES FAHRENHEIT.									
	Baltimore.	Worcester.	Boston.	Chicago.	Melbourne.	Berlin.	Dantzic.	Paris.	London (Greenwich).
Jan.	34.3	23.7	26.9	24.0	66.3	32.8	27.6	37.2	38.8
Feb.	37.0	25.6	28.3	27.8	65.8	33.6	28.7	40.2	40.4
Mar.	42.1	33.1	34.1	34.4	63.9	39.0	34.9	44.6	42.3
Apr.	53.2	45.8	44.4	46.2	58.7	47.1	42.3	50.3	48.2
May	63.9	56.2	56.8	56.2	53.3	54.7	50.3	55.4	54.0
June	72.3	65.8	66.4	66.4	49.7	62.9	60.0	61.8	60.4
July	78.6	70.9	71.9	72.0	47.6	66.7	63.8	66.0	63.6
Aug.	74.5	67.7	69.9	70.8	50.4	64.9	62.2	65.0	63.3
Sept.	68.2	60.9	63.1	64.2	53.1	58.7	56.2	59.0	58.5
Oct.	58.0	47.9	52.1	52.6	57.0	48.9	45.6	50.4	50.9
Nov.	47.1	39.3	41.1	39.0	60.2	39.9	36.8	43.2	43.0
Dec.	38.5	27.7	31.5	30.4	65.0	32.8	29.6	37.0	39.9
Annual	55.6		48.9	48.7	57.6	48.5	44.9	50.8	50.3

GENERAL DRAINAGE.

The City of Baltimore has never had in the past any systematized drainage.

The extensive water front along which the town was first built, afforded, with the intersecting streams already mentioned, every facility for getting rid of surface water, and all waste water polluted by domestic use was allowed to take the same course through the open street gutters. Whether it was greasy refuse from the kitchen, dirty suds from the laundry, or foul water from the bath; all followed that course

*Furnished by the U. S. Weather Bureau.

toward the harbor which the graded surface defined, dropping the heavier filth in the gutters as the flow progressed.

Cesspools, or pits in the rear of every lot, are, and have been from the beginning, the receptacles for human excreta.

These pits are lined with a brick curbing generally laid dry, so that ground water has ready ingress and egress, until the joints of the brick lining become more or less silted up and obstructed by lapse of time and the accumulation of deposited matter.

That these primitive methods could have been tolerated here for so long a time is probably due to the fact that, until the introduction of the Gunpowder water in 1881, the liberal use of water for such purposes as water-closets and baths was checked by a limited water supply. That they should not have produced greater injury to the public health may be attributed to the specially salubrious location of the city, and to the fact that its topographical features are particularly favorable to a thorough cleansing of the streets and gutters by every heavy rain.

With the growth of the city, the extension of its paved streets, and the covering of its vacant lots with continuous rows of houses, the rainfall, no longer held back or absorbed by the exposed surface of the ground, is hurried through the gutters to the lower grounds, whence the old channels can no longer discharge the increased quantity with sufficient rapidity, causing the overflow of gutters into cellars, and involving damage to property.

This has led within a few years past to the construction of numerous sewers, so-called, to carry off the storm water, which have been built on the old and natural lines of drainage and, it is believed, without any reference to the ultimate disposal of the street washings and solid matter carried down with and by the water.

STORM-WATER DRAINAGE.

The assumption that the separate system will be adopted by the city, and that the present storm-water drains will be freed from sewage, and devoted only to the purpose for which they were constructed, has made it incumbent upon the Commission to consider their adequacy for this purpose. It

has, therefore, caused such examination to be made, and a detailed report of the result will be found as Appendix B to this Report.

CESSPOOLS AND WATER-CLOSETS.

Whilst the demand for better storm-water drainage has been pressed upon the attention of the city authorities, the growth of the city in population and wealth, and the development of its water supply system, which now affords a daily volume to each head of its population much in excess of actual needs, have stimulated domestic consumption, and the use of water-closets, baths and other house fixtures, has become general.

Increased employment of water-closets has been necessarily followed by much more rapid filling up of cesspools, and property holders have been glad to avail themselves of access to the storm-drains, whenever permission to do so could be secured, for the purpose of getting rid of the overflow of cesspools.

This privilege was at first refused absolutely, then granted conditionally, and later accorded freely, then again resolutely refused, and at present once more permitted under circumstances and conditions appealing to the favorable judgment of the authorities.

Where storm-water drains have not been available, permission has been readily granted to individuals and corporations to construct private drains from their premises to the nearest watercourse, and there are now very many of these obstructing the beds of the streets with numerous, and frequently parallel lines discharging their filth into the stream, principally into Jones' Falls, or directly into the harbor, befouling it and creating a nuisance only to be removed by the expensive process of dredging.

The cost of these special drains is usually so great that only corporations or persons of wealth can undertake them, leaving the less fortunate owners of adjoining tenements full evidence of the advantages of drainage, but without the ability to profit by the example placed before them.

The city has not been without the experience of having the overflow from the cesspools of a whole row of large

houses conducted by a private drain-pipe, and discharged into the street gutter at some little distance from the houses, for the benefit of which the arrangement was made; the builder of the houses having availed himself of this method, to save himself the expense of deeper pits or a costly private drain to the Falls.

Whilst this, and doubtless other similar cases have been discovered and corrected, yet it is safe to say that our street gutters to-day are not everywhere free from similar contamination.

The emptying of cesspools, and the disposal of their contents is always a troublesome and expensive matter under existing conditions. The pit when first dug of reasonable size and depth will, under favorable circumstances, serve its purpose for a long time without causing trouble or expense. The fluids will disappear in the surrounding soil, whilst the accumulation of solid matter is so slow as to be unnoticeable. So long as the fluid passes off, or does not rise so high in the pit as to suggest overflow, all is satisfactory and no complaint is heard.

It may create a nuisance in a neighbor's cellar, but the source of the nuisance in such case, is not readily traceable, unless it be immediately adjoining, and the neighbor, after a vain search for the cause, is made to believe that the trouble is local and peculiar to his own premises; that he has a damp cellar which he is advised to pave. This perhaps he does, but probably realizing that the paving has only served to partly conceal from view what is still evident to his other senses, he finally, and perhaps not until after a case of sickness in the house, determines to move elsewhere.

The pit itself, after a time, which may be many years, becomes so silted up that the foul matter reaches to the surface of the ground, and becomes a recognized nuisance, both to the owner and his neighbors.

Resort is then had to the night-soil scavenger, who cleans the pit more or less thoroughly, carting the contents to the points which the city authorities have established as dumping places, where the filth is dumped into scows provided by a party who contracts with the city to receive and dispose of it. The pit when emptied serves again its original purpose, but by reason of the silting up already described, does

not pass the fluid into the soil as readily as at first, and it soon becomes again necessary to empty it. The process, as said before, is expensive, and the owner, after noting its recurrence with increasing frequency, avails of proffered advice to sink the pit deeper or to dig a new one. The expedient is found only temporarily effective, however, for the more or less saturated soil does not drain off the fluids as well as at first.

In many places, particularly where lots are shallow or the ground fully occupied for business purposes, newer pits have been dug in the cellars under the house proper.

Such is the ignorance or indifference as to the danger to health arising from this last cause that instances could be cited where such pits exist in the cellars of large and costly dwellings in the central and most fashionable part of the city, and this, too, where large and ample lots make no such course compulsory.

Instances are not unknown where, the lots being fully occupied, the owner has preferred to place his new pit in the public street, rather than in his own cellar, and has so constructed it after obtaining permission from the authorities.

This is not an exaggerated picture of the conditions which prevail in Baltimore to-day, being of course greatly worse in the older portions of the city than in those more recently built upon.

In his annual reports from year to year, the Commissioner of Health has called attention to the existing conditions in this regard. In his report for the year ending December 31, 1895, he says:

“It is not asserting too much to declare that our privies are the most dangerous enemies of our lives and happiness. The contents of these abominable receptacles have free access to the soil, and saturate the ground with liquid filth to such a degree, that specimens of sub-soil water taken from different depths, and in different sections, yield a large percentage of organic matters, the products of animal excretion.

“Many of them overflow, and the liquid contents flow into yards and gutters, emitting most offensive odors, which are a fruitful source of disease, operating indirectly in its production, and directly in lowering the vital stamina of the unfortunates compelled to breathe a polluted atmosphere.”

How much of the water-closet and privy or cesspool drainage now reaches the harbor through the public storm-water drains, or by those privately owned, your Commission has no means of ascertaining, nor can it estimate the amount which filters through the soil. That it is already large is, however, manifest, for of the 52 million gallons of pure water now daily distributed throughout the city, and which must find its way to tide level, we have only account of about 50,000 gallons of foul liquid daily removed from the cesspools; or about one-tenth of one per cent. of the whole.

These existing conditions have long been the subject of anxious consideration to such of our citizens as recognize the fact that, though our city has for a century escaped any serious epidemic, it is nevertheless constantly exposed to attack, which may be less readily repelled when surrounded as we are by these filthy accumulations. It is also to be noted that if once seriously attacked by an epidemic, exhalations from cesspools, loaded with the foul and dangerous dejecta of disease, are not unlikely to increase the liability to a subsequent recurrence.

FINAL DISPOSAL OF NIGHT SOIL UNDER EXISTING METHODS.

The contents of cesspools, collected by licensed scavengers, is permitted to be delivered only at the localities authorized by the Board of Health. Of these there are now two, one at what is known as Winans' Wharf, near the extreme southern point of the city, and the other at Foley's Wharf, at the extreme southeastern city line.

At these dumping places the matter, conveyed thither in sealed barrels or tanks, is emptied into scows or barges supplied by the contractor who has engaged with the city to remove the same to localities beyond the city limits, where its deposit shall not create nuisance.

The barges when filled are towed to one of some thirty-five different localities, on Bear Creek, on Middle River or on North Point Creek, where the contents are transferred by pumps to pits or tanks, whence it is purchased and removed in tank wagons by the farmers of the several neighborhoods as needed by them, and directly applied to their fields.

The heavier portion which may collect in the bottom of the tanks, if not removed by the tank wagons of the farmers, has been applied to the surface of fields owned by the contractor, where it has been worked up into a compost, and sold in that way as a fertilizer.

It does not appear from inspection of the contractor's plant that any portion of this matter is allowed to waste into the creek; yet on one of several visits to Bear Creek the water seemed to be a good deal befouled, which, taken in connection with the statement of a party long resident in this locality, that the fish, formerly abundant, no longer frequent the creek, leads to the inference that more of the foul matter finds its way to the creek than is easily apparent.

VOLUME OF SEWAGE.

The quantity of sewage to be collected and disposed of may be fairly estimated from the population and the average water consumption, with a proper allowance according to actual conditions of construction for the accession of rain water from the surface or of ground water from below.

It has already been stated that, in providing a system of sewerage which shall be fully adequate for the next thirty years at least, the growth of population in that time must be provided for, and we have estimated that in 1925 the population will probably be so near a million of people, that we may without much probable error assume that as the number.

It has been shown also that the present water consumption approaches the amount of one hundred gallons per head of present population. This is believed to be adequate for future requirements. Whilst the tendency in the past has been to increasing consumption per head, it is not thought that this will continue.

It will be met by a realization on the part of the city authorities, of the enormous waste beyond absolute requirements involved in even the present rate of consumption, and of the greater cost of the water to supply future demands by the necessity of pumping to higher elevations in what are now the suburbs of the city.

This, with the further realization that most of the water

thus distributed must be carried away by the new sewers, much of it at a further cost of pumping from the lower levels, will lead to the adoption of methods for checking waste, such as have already been brought into use in other places.

It may here be noted that our neighbor, Philadelphia, which in 1885, consumed seventy-two gallons per head per day, and which had reached a consumption in 1890 of one hundred and thirty-two gallons per head per day, is now reported by its Water Engineer as having attained in 1895 one hundred and sixty-two gallons per head per day.* The city is now agitating the question of checking the wasteful consumption which an intelligent authority, who has been considering the question of an improved supply of water, states may in all likelihood be reduced to one hundred gallons per head by the year 1900.†

Of the ninety-five gallons per head, now used by the present population of Baltimore, quite a large but uncertain proportion serves for fountains, street sprinkling, garden hose, etc., and will find its way in the future, as it does at present, to the storm-water drains, and not to the new sewers.

Nevertheless, in estimating the volume to be disposed of by the new system, it has been deemed prudent to add thirty per cent. to the present consumption per head, to provide for contingencies of all kinds, including such admission of rain water and infiltration of ground water as it may be difficult to exclude.

We thus have one hundred and twenty-five gallons per head of population to provide for, and with the prospective ultimate population of one million, a total of certainly 125,000,000 gallons which the new works must be capable of receiving and removing each day.

It has nevertheless been deemed prudent by the Consulting Engineers from the information supplied to them to provide for 150 gallons per head of population, and their estimates have been made on that basis.

* Annual Report of the Philadelphia Bureau of Water, for 1895.

† Report on the City's Water Supply to the Woman's Health Protective Association of Philadelphia, by Allen Hazen.

SEWAGE DISPOSAL.

It is very generally agreed by all who have knowledge of the subject that the removal of human excreta from the immediate neighborhood of human habitations should be effected as rapidly as possible. A distinguished English engineer has said of it:

“It is an offense to the senses and a menace to health as long as it remains.”

The recognized modern methods of sewage disposal may be enumerated as follows:

First. Dilution by discharge into the sea, or into large bodies of fresh water, lakes or rivers.

Second. Chemical Precipitation.

Third. Intermittent Filtration and Irrigation of Crops.

These several methods of disposal are more or less available, according to the conditions affecting each particular case.

1st. DILUTION.

Where a large body of water, not used for drinking purposes, is near at hand, with currents such that dilution may be quickly effected to an extent sufficient to leave no apprehension of offense to riparian or other interests, a discharge of the sewage into it may be the most economical as well as the most convenient method of disposal. If it be the ocean into which such discharge is made, the disposal may be considered as final.

When, however, as most frequently occurs, the outfall is into a river or bay, greater precaution is necessary in order to guard against objectionable deposits due to the peculiar regimen of the river or the currents of the bay, and due consideration must be given to possibly changing conditions in the future.

The great facility with which water-borne sewage may be put out of sight by discharge into adjacent rivers, lakes and bays has led to much abuse of this method of disposal. A practice that might be tolerated with the population of a village or that of a small town often finds its limit before the young but rapidly growing city, into which the village or town has developed, finds itself ready to cope with the nuisance which has grown up about it.

Amongst many instances of this sort which might be cited and which have been met by a thorough and complete system of disposal by dilution it will suffice to mention as examples the cities of Boston, Chicago and Memphis.

BOSTON.*

A high and increasing death rate in the City of Boston, which had reached 30.5 per 1,000 in 1872 and was 28.4 in 1873, led to the appointment, in 1875, by the authority of the Mayor and Board of Aldermen, of a Commission, consisting of two civil engineers and a person skilled in the subject of sanitary science, to report upon the existing sewerage of the city, its future wants and an approximate estimate of the expense of any plan or plans for a system of sewerage submitted by them.

These gentlemen presented their report in the following year.† It is not without interest for us to note that, giving the experience and practice of other cities, they speak of the conditions existing in Baltimore as follows:

“Most of the first-class dwellings and the hotels have water-closets discharging into cesspools made in the porous soil of the city. In some cases their liquid contents are emptied into the sewers. Street washings and the slop-water discharged by the sewers, however, have made the basin very filthy and foul-smelling. Near the city the tide rises and falls only one foot and a half, an incurable difficulty in the way of disposing of the sewage within the city limits. Already a main-drainage scheme is talked of, to take all the sewage to a point several miles below the city, and to abolish cesspools, but it has not yet assumed a definite shape.”

There were already existing in Boston upwards of 125 miles of sewers, which received storm water and such house drainage as reached them and discharged into the nearest or most available part of the harbor, but which were interrupted in their flow by the state of the tide, so that not only might the sewers be full at high tide, but the sewage was liable to be forced back into the houses by the action of the tide.

*See Report on Boston Main Drainage, by Eliot C. Clarke, C. E., and the various Reports of the Metropolitan Sewerage Commission.

†Report of Commission on The Sewerage of Boston, 1876.

The Commission states, "There are in use now in various parts of the world three methods of disposing of the sewage of large cities, where the water-carriage system is in use."

"First. Precipitation of the solid parts, with a view to utilizing them as manure and to purifying the streams."

"Second. Irrigation."

"The third way is that adopted the world over by large cities near deep water, and consists in carrying the sewage out so far that its point of discharge will be remote from dwellings, and beyond the possibility of doing harm. It is the plan which your Commission recommends for Boston."

For effecting this the Commission recommended the construction of a system of intercepting sewers, which should receive the discharge from the existing sewers and convey the whole to a point in the outer bay, whence the sewage would be swept to sea by the outgoing tides which have a mean rise and fall of about ten feet.

The estimated cost of the works was placed at \$6,551,000.

At the ensuing session of the Legislature an enabling act was obtained, authorizing the construction of the works, which was immediately followed by action of the Mayor and City Council adopting the general recommendations of the Commission and appropriating \$40,000 for making further necessary surveys and estimates by the City Engineer.

In July, 1877, that officer reported a definite scheme corresponding in all essentials to that recommended by the Commission. He fixed the point of discharge at Moon Island, whence the sewage would be swept out at ebb tide by currents not capable of affecting unfavorably the inner harbor.

The revised estimate placed the cost of the work at \$3,712,700.

On January 1, 1884, the connections between the common and intercepting sewers were first opened at a total cost reported to December 31, 1885, of \$5,278,786.44.

It must be observed here that this sum is the cost only of the intercepting and disposal system, into which is received the sewage from the network of district and lateral sewers, of which some 200 miles or more were already in existence when the disposal works were opened to a connection with them.

Through the courtesy of the present City Engineer of

Boston, Mr. William Jackson, special facilities were afforded a member of your Commission for an examination of this important work, which in its successful operation, fulfilling every anticipation of its projectors, illustrates again the importance of thorough investigation before undertaking works of such magnitude.

The highly satisfactory working of this system has since led to its extension to the suburban districts along the Mystic, Charles and Neponset valleys. Under the direction and control of a Board of Metropolitan Sewerage Commissioners a scheme was formulated for disposing of the sewage derived from and collected by the various towns and villages included in an area of 159 square miles, surrounding Boston in all directions and known as the Metropolitan Sewerage District.

The sewage is collected by a large number of intercepting sewers which, with the aid of several pumping stations, serve to convey it to points of delivery in the outer harbor.

A portion reaches Moon Island through the outfall sewer which serves the City of Boston. Another and the larger portion is conveyed through a distinct outfall sewer to Deer Island on the north side of the outer harbor, distant some three miles from Moon Island, where it is discharged and swept out by the tides.

Up to October 1, 1896, about 53 miles of these sewers had been constructed with an expenditure of \$4,956,555. Further extension at a cost of about $1\frac{1}{4}$ millions has already been authorized.

CHICAGO.

The City of Chicago, originally located on a perfectly flat prairie only a few feet above the level of Lake Michigan, which then dashed its storm waves into the streets of the city, is intersected in several directions by the Chicago River and its branches, emptying with very sluggish current into the lake.

Some 35 years ago in order to effect an adequate fall for the sewage of the city to the river and lake, a scheme was undertaken at enormous cost to raise the level of the city some 5 to 12 feet. This project was carried out and property owners raised their houses, sometimes a whole block at a time, to the new level. The water supply of the city was at

the same time derived from the lake by an intake located a mile or two from the shore.

The growth of the city since that time has demonstrated the necessity for a further radical change. So befouled has become, not only the river, but the whole lake front, that after extending the fresh water intake to a distance of 4 miles from the shore, without thereby obtaining the relief from apprehension of pollution which should be guaranteed to the inhabitants of a large city * in regard to their water supply, it has been determined to correct the evil radically, and, instead of discharging the sewage into the lake, to reverse the direction of the river's flow, and with the aid of the water of the lake, to wash out the river, sewage and all, and, through a canal being constructed for the purpose, to discharge the whole into the Des Plaines River and thence to the Illinois River, a tributary of the Mississippi.

It has been concluded, after much investigation and with the aid of several of the most experienced engineers in the country, that the dimensions of the canal shall be ultimately such as to admit of a dilution by flushing from the lake at the rate of four cubic feet per second for every 1,000 of population of the city.

This it is claimed will secure a degree of dilution for the sewage sufficient to prevent its becoming offensive at any point of its course, or even objectionable in any way when it reaches the Mississippi.

This great work is now in full progress at an estimated cost of upwards of \$32,000,000.† When completed it is expected to afford a ship canal between the lakes and the Mississippi with a least width of 160 feet and a depth of 18 feet.

It must be remembered that here, as in the case of the Boston works, the cost given is that of the intercepting or disposal system. Chicago already had in 1895 some 1,248 miles of sewers, the cost of which aggregated nearly \$17,000,000.‡

2d. CHEMICAL PRECIPITATION.

Where no large body of water is available for dilution, or where in river or bay the presence of crude sewage is objec-

* See Water Supply, by Prof. W. P. Mason.

† See Proceedings of the Chicago City Council for March 1, 1897.

‡ See Report of the Chicago Department of Public Works for 1895.

tionable, the difficulty may be met by a partial purification of the effluent, which may be effected by what is termed chemical precipitation.

This process consists in conducting the sewage, at the place of outfall, first through strainers to remove the coarser matter, and then into tanks, where it is treated to an admixture of some coagulant, such as sulphate of alumina or sulphate of iron.

It is then passed very slowly through a series of settling basins, where time is allowed for the deposit of the suspended matter, to accelerate and facilitate which action is the purpose of the chemical admixture.

If these basins be of sufficient extent, and time enough be allowed in the process, it is claimed that the effluent may pass off in a condition so much improved as not to be seriously offensive to either sight or smell, but the precipitation thus effected is at best but partial, and the effluent still retains in solution about one-half of the organic matter originally held therein.

The deposited matter, technically known as *sludge*, remains, however, in the bottom of the basins, and must be removed and disposed of in some special way.

In order to diminish its bulk, this sludge is sometimes submitted to high pressure to get rid of the large amount of water which it retains, amounting to some ninety per cent. of its whole volume.

The solid cakes resulting from this pressure are then burned, or disposed of as fertilizer, although it does not appear that the farmer attaches much value to them for this purpose.

The City of London now treats by precipitation its enormous volume of sewage, amounting, in 1895, to about two hundred and five millions of gallons per day,* and has established a line of steamships, specially designed and constructed for the purpose, to convey the residuant and unpressed sludge to the North Sea, where it is dumped, the ship returning for another load.

In 1893 there were in use five sludge steamers of 1,000

*See Reports of the Chief Engineer of the London County Council, and Report on Sewage Purification to the County Borough of Leeds, by Thos. Hewson, City Engineer, 1894.

tons capacity each, and two were to be added soon. These transported 40,000 tons per week.

There are numerous other examples abroad of the use of this method of disposal, usually made necessary to correct the defilement of rivers and harbors polluted by the discharge of crude sewage into them. Leeds, Manchester, Birmingham, Bradford, Coventry, Salford, Sheffield and Southampton in England, Glasgow in Scotland, Amsterdam in Holland, Frankfort in Germany and Boulogne in France all employ it. Of these we shall only cite Glasgow.

GLASGOW.*

Until 1894, the sewage of Glasgow was discharged into the Clyde, making that important stream perhaps the most foully polluted of navigable rivers.

Its population of about 700,000 is dense, occupying but $18\frac{1}{2}$ square miles of area. The precipitation plant recently put in operation, takes, however, the sewage of but 300,000 persons from an area of only 4 square miles, the excreta from the bulk of the population being still collected in pails by contractors who dispose of it at a profit of from 25 cents to 50 cents per ton.

The works have a present capacity of 12 million U. S. gallons of sewage per day, but are designed to treat about twice this amount eventually.

They cover 28 acres of ground and have cost about \$335,000 exclusive of the cost of the ground.

The sewage is received from a $7\frac{1}{2}$ foot main through a coarse grid intended to catch heavy floating matter, and is thence intercepted by rotary screens of $\frac{5}{8}$ inch opening, which collect all other floating matter and deposit it in a receptacle, whence by suitable mechanical arrangement it is removed at proper intervals to a destructor furnace and is there consumed.

The sewage, freed of the heavy matter, is led to a pump-well, whence it is lifted by centrifugal pumps to the mixing pit, where the chemicals are introduced. Sulphate of alu-

*See Engineering Record, Vol. XXXII, page 461; Municipal Government in Great Britain, by Albert Shaw, and a Description of the Sewage Purification Works by the Manager, Thos. Melvin.

mina and lime are the precipitants now used in varying proportions according to the nature of the sewage, the character of which varies greatly during the day, owing to the large amount of waste from manufacturing establishments which reaches the sewers during working hours.

The sewage after receiving the chemical admixtures is led to the precipitation tanks or basins, 24 in number, 50 feet by 40 feet in area and 6 feet in depth. These are so worked intermittently as to allow the sewage to rest in the tank receiving it for 45 minutes, which suffices to effect the required degree of precipitation. The effluent valves, arranged to draw off the water from the upper surface, are then opened and the effluent is passed across a series of 24 aerating beds or channels of brick, each 43 feet by 40 feet in size. From these the effluent is distributed to the filters, of which there are 20 of coke, each 40 feet by 10 feet in area and $3\frac{1}{2}$ feet in depth. After passing the coke filters 72 per cent. of the organic matter has been removed. The effluent thus considerably purified is then distributed to 40 sand filters, each of which is 40 feet by 38 feet and $2\frac{1}{4}$ feet in depth. These remove a further quantity of organic matter, so that after passing them 81 per cent. of that originally contained has been abstracted and the effluent in this condition passes into the Clyde.

The sludge from the field precipitation tanks is led back to the works, where it is collected in small settling tanks and allowed to further precipitate. It here loses about 50 per cent. of the water which it contained when it left the field tanks. It is then raised by compressed air to a mixing tank where hot lime is added, and is then forced by the same means to the rams and presses. There are seven presses, each capable of holding $1\frac{1}{4}$ tons of pressed sludge cake. When thoroughly pressed the cake is dropped by chutes into railway wagons and so removed to the city farm. Sixty tons of these cakes are said to be the daily output.

The cost of operating the works for the year 1894-95 is stated to have been \$13.60 per million gallons.

The sewage treated at Glasgow is probably much denser than would be that at Baltimore, and therefore the cost of operating similar works here might cost less for chemicals, perhaps altogether much less. At the same rate it would

amount, for the treatment of the sewage of Baltimore, to \$204,765 per annum when 330,000 persons are connected with the sewers, and to upwards of \$600,000 per annum eventually for the estimated future population of one million; and this without including cost of maintenance of the general system of sewers, and also without regard to interest and sinking fund on capital outlay.

These figures at least serve to illustrate the costly expedients to which are driven other cities less fortunately situated than our own.

In our own country the employment of chemical precipitation is not very extended, and the establishments are generally on a small scale. They may be found at Long Branch, N. J., Round Lake, White Plains, New Rochelle, Chautauqua, Sheepshead Bay, and Coney Island, N. Y., Alliance and Canton, Ohio, and Worcester, Mass. The latter is the largest and by far the most important work of the kind on this side of the ocean, and is the only one which it is thought necessary to describe here.

WORCESTER.*

The city of Worcester formerly discharged its sewage in a crude state into the Blackstone River, a small stream emptying into tidewater near the head of Narragansett Bay. The continual complaint of its pollution, emanating from the numerous villages and mill-sites with which its banks are studded, led finally to energetic action for the abatement of a nuisance which had, in 1883, become unbearable.

The city authorities shortly thereafter authorized the city engineer to investigate existing systems at home and abroad with the view of ascertaining the best method of meeting the conditions there prevailing. He visited the most important plants in Europe and presented, in 1887, his report and recommendations for a chemical precipitation plant as that most suitable for Worcester. This plan was adopted, and in December, 1890, the same officer reports that the sewage disposal works have been practically completed.

*See Report of the City Engineer on the Disposal of Sewage, 1887, and the Annual Reports of the Superintendent of Sewers.

The process consists of the admixture of chemicals after a preliminary screening. The flow of the sewage after mixing is over a weir to a series of 26 settling tanks; of which 16 have areas of 100 feet by $66\frac{2}{3}$ feet, and 10 have $166\frac{2}{3}$ feet by 40 feet. All are 7 feet deep. Through these it flows slowly and continuously, depositing the heavier matter on the way, finally reaching an effluent drain which discharges the clarified sewage into the Blackstone River.

The population connected with the system is about 80,000 and the quantity of sewage treated daily about $15\frac{3}{4}$ millions of gallons. Of this amount about $6\frac{1}{2}$ millions of gallons are sewage proper. The remainder is principally clean brook water and rain-water, both of which it is proposed at an early day to exclude from the sewage by improvements now in progress.

The sewage of Worcester contains a very large amount of sulphuric and muriatic acids, refuse from manufacturing establishments, which it is necessary to neutralize in order to effect precipitation. This necessitates the admixture of very large amounts of lime, 1,030 pounds being used per million gallons or about 3,000 tons per annum in the year 1895.

Whilst the same proportion of lime might not be required for the sewage of Baltimore, not complicated to the same extent with manufacturing wastes, yet taking the working of the Worcester plant, said to be very economically administered, as a criterion, Baltimore would require for the 50 million of gallons estimated to flow from its 330,000 persons at first installation, about 25 tons of lime per day, or for the ultimate one million population about 75 tons per day.

From recent reports from Worcester we learn that the annual cost of the purification of the sewage amounts to 45 cents per head of the population, or to \$6.30 per million gallons treated. If we apply the same rate per million gallons to the estimated amount of Baltimore sewage when 330,000 persons are connected with the system, the annual cost would be \$114,975.00, increasing to \$344,925.00 when the system serves one million people.

FEROZONE AND POLARITE PROCESS.*

A modification of the Chemical Precipitation method is found in a comparatively new process, first introduced at Acton, England, some eight or nine years ago. Since then it has been adopted by some ten or more English towns, including Huddersfield with a population of about 100,000, and has been authorized by the cities of Rouen, Toulon and Bordeaux, in France.

It is known as the *Ferozone and Polarite Process*, and consists, after the straining already mentioned, in mixing with the sewage in the receiving tanks a quantity of what is known in the process as *Ferozone*, a composite substance containing over 25 per cent. of ferrous sulphate and 19 per cent. of magnetic oxide of iron, with 11 per cent. of aluminum, calcium and magnesium. This acts both as a disinfectant and coagulant.

The sewage thus treated passes through the series of settling basins, where the sludge is collected as previously described; but instead of then discharging the effluent, still retaining about one-half of the original organic matter, it is conducted to a filter some 30 or 36 inches in depth, composed of sand and gravel, and including 10 inches of sand and *polarite* mixed in nearly equal proportions.

Polarite is another compound containing about 54 per cent. of magnetic oxide of iron and 25 per cent. of silica. It is practically insoluble, and does not appreciably corrode, lose weight or alter in any way. Its remarkable efficiency seems to be due to its capacity to absorb or condense oxygen in large volumes, or *polarize* it, to use the term which comes to us with an account of the process from abroad.

By means of this property the organic matter is oxidized or burnt in its passage through the filter, and as the *polarite* is indestructible, the action of the filter may be continued indefinitely with very brief periods of rest.

The investigations of noted scientists bear strong testimony to the value of this process, which seems to be sustained by such men as Prof. Frankland, Sir Henry E. Roscoe, Dr. Arthur Angell and Messrs. J. Carter Bell and Naylor.

*See Proceedings of the Institution of Civil Engineers, Vol. CXVII, and Sewage Disposal, by W. Santo Crimp.

These and other investigators have found by this treatment a reduction varying from 83 per cent. to 98 per cent. of the organic matter and from 98 per cent. to 100 per cent. of the bacteria originally held by the sewage.

From Huddersfield,* where are located the largest works employing this process thus far erected, we learn that "the system is satisfactory so far as the capacity of the works goes."

3rd. INTERMITTENT FILTRATION AND IRRIGATION OF CROPS.

The treatment of sewage by intermittent filtration is based upon the ascertained fact that if decomposing organic matter, held in suspension in water, be discharged upon a coarse, sandy or gravelly soil, properly under-drained so as to act as a filter, and the water be allowed to drain away, leaving the filter bed comparatively dry, so that the air will have access to its interstices, the organic matter so deposited will be effectually assimilated by minute organisms, which will develop in the bed under the conditions of alternate flooding, draining and exposure to the air.

Sewage thus treated may be so thoroughly purified, and the effluent water pass off so clear and limpid, that fish will thrive in it, whilst the filter bed is continually renewed and maintained in its original efficiency by short periods of rest, aided perhaps occasionally by a light harrowing of the surface.

Numerous examples of this method of treatment may be cited both in this country and abroad. Its employment, however, at least in the United States, has never as yet been on a very large scale. This is probably due to the fact that but rarely can there be found in the neighborhood of a large city a sufficient body of land possessing the necessary characteristics of soil, combined with suitable features of surface and drainage and still available for such a use at any reasonable cost.

Under this system the sewage may be directly applied to the irrigation of growing crops.

* For a description of these works, see "Industries and Iron," for May 1, 1896.

The economical results which at first sight might be anticipated from this form of disposal are not always realized, for the reason that it is difficult to adjust the constant and regular flow of the sewage to the irregularly intermittent requirements of the crop.

In periods of excessive rainfall the farmer will need no additional irrigation. To force the sewage on his land when already surfeited with moisture would injure the crop. It must, however, be disposed of somewhere, and hence other provision must be made for the whole, or very nearly the whole, just as though no portion were applied upon the cultivated land.

It may, nevertheless, be possible to make a portion of the land used for intermittent filtration available for the growth of crops, but such use will be of an incidental character, requiring a larger area of filtering ground.

Where, however, the drainage of the filter beds is not into waters used for drinking purposes, and where, therefore, a uniformly high standard of purity in the effluent is not essential, a portion of the filter beds may be made to take occasionally a quantity of sewage in excess of the normal allowance, thus admitting of a corresponding diminution in other sections of the filtering area, and making possible a special regimen for that portion of the ground devoted to agriculture.

It will thus be seen that *intermittent filtration* and *irrigation* are the same in principle. With the first the main object is to secure as pure an effluent as may be required with a minimum outlay for land. Hence rapid filtration is sought and under-drainage becomes necessary, frequently aided by the removal of the surface loam, some few inches of which are generally to be found on even the most sandy soils. Under such conditions successful cultivation of crops is not always well assured.

On the other hand, with irrigation a proper treatment of the land with reference to the production of a crop dominates the application of the sewage, and the purity of the effluent is a secondary consideration, or, if required, is attained by increasing the area over which the sewage is distributed.

The latter system is in common use in Great Britain, having been employed for a portion of the sewage of Edinburgh for over two centuries, and there being over two hundred sewage

farms in England alone at the present time, as at Birmingham, Croydon, Oxford and Wigan.

It is, however, on the continent of Europe and in the Australian colonies of Great Britain that some of the most instructive examples of this method of sewage treatment may be found.

Berlin, Paris, Zurich, Breslau, Dantzic, Freiburg, Florence, in Europe; Calcutta, in British India; Adelaide and Melbourne, in Australia, are all now to a greater or less extent discharging their sewage upon land.

In our own country the defilement by sewage improperly disposed of has been seriously appreciated only within a comparatively short time, so that we find fewer working examples of land disposal, and none on a scale at all comparable to what can be seen abroad. We may cite, however, Amherst, Brockton, Framingham, Marlborough, Gardner, Lenox, Medfield and North Brookfield, in Massachusetts; Pawtucket, in Rhode Island; Altoona and Wayne, in Pennsylvania; Bristol and Meriden, in Connecticut; Freehold, Plainfield, Princeton and Summit, in New Jersey; Oberlin, in Ohio; Pullman, in Illinois; Hastings, in Nebraska; Paris, in Texas; and Salt Lake City, in Utah; and must not omit an example very near at home where, on quite a small scale, the system may be found at work at Roland Park, Baltimore County.

At Brockton, Mass.,* the sewage of the city, containing in 1895 a population of some 33,000, is being disposed of by pumping to an elevation of about forty feet to a sewage farm of some 30 acres. At the end of 1895, the date of our latest advices, the sewer connections already effected served not more than 3,000 people, and the daily flow of sewage to the field averaged about 270,000 gallons. The sewage is reported as highly diluted by the infiltration of ground water and is discharged in doses of from 75,000 gallons to 100,000 gallons upon 23 filtering beds, averaging about one acre each. Each bed receives a dose every third day, and for a portion of the year every second day.

The cost for the year 1895 of running the pumping station and the filter beds was about \$6,000. Although the severity

*See various Reports of the City Engineer, and Report of the Mass. State Board of Health for 1895.

of the winter climate of Brockton has interfered somewhat with the effective operation of the system, it is stated that no nuisance has been occasioned, and that its working has been most satisfactory.

At South Framingham, Mass., a town of something less than 10,000 inhabitants, there is working a system of filtration and farm irrigation which affords an interesting and instructive illustration of what may be effected by this method of treatment.

The natural drainage of the town being on the watershed supplying the City of Boston, it was determined that the disposal should be on ground beyond this area. Under the system adopted the sewage, from which both storm and ground water are as far as possible excluded, is collected to the amount, in 1896, of about 460,000 gallons daily, and is then pumped through a 12-inch cast iron main, $1\frac{7}{8}$ miles in length, to an outfall 40 feet above, on a farm of some 90 acres of porous sandy soil, of which, when visited in July, 1896, by a member of this Commission, only 20 acres were under cultivation, and serving a population connected with the sewers estimated at 7,000.

A luxuriant crop of corn was under cultivation, which the farmer superintendent stated could at that season take very much more sewage than the system supplied.

The effluent was examined and appeared to be a clear and inviting drinking water, of which the superintendent did not hesitate to take a copious draught.

The working of the system appeared to be, as claimed for it, satisfactory in all particulars. That this is the case may be inferred from the fact that, there being no suitable soil available for the filtration beds in the town of Framingham, the required conditions were sought and found in the adjoining township of Natick, whose population, somewhat indignant at first at so unwelcome an intrusion, have since become not only reconciled thereto, but are now introducing a similar system for their own town and, at the time of the visit referred to, were preparing a series of filtration beds immediately adjacent to the farm here described.

PARIS.*

Paris is a compactly built city, including some $2\frac{1}{2}$ millions of inhabitants, housed in but 30 square miles of territory. Its so-called sewers were merely open ditches until 1750, when they were superseded by covered channels. In 1851 the first modern sewer was built in the Rue de Rivoli, and in 1856, Belgrand's scheme of sewerage was adopted, which has since been elaborated into the present magnificent system.

Water-closets not being in use, the sewers were not designed to take excreta. Their slopes were necessarily flat, and being liable to deposits, they were designed of large dimensions, so that they could be readily cleansed by hand or by mechanical appliances. This renders their maintenance costly, amounting now to a very heavy annual expenditure.

There is some compensation for this found in the fact that their size makes it possible to place in them not only electric and other conduits of small size, but large water mains as well, which are supported on brackets above the sewage, and thus is avoided the constant disturbance of the street surface, so destructive to all good pavements, and elsewhere a source of heavy annual expense.

A recent law compels the use of water-closets, but thus far the connections made do not take more than one-third of the entire excreta, the remainder being still deposited in cess-pools as in the past.

In 1893 the average daily discharge of the system was 117,500,000 U. S. gallons, of which but three-fourths of one per cent. was excretal matter. The sewage is collected along with the storm water by some 600 miles of lateral sewers into interceptors, which are arranged with storm overflows to discharge from two-thirds to three-fourths of the storm water into the river Seine. The remainder accompanies the sewage and is lifted some 33 feet by suitable pumps and is then discharged on irrigation fields at Gennevilliers, a suburb on the river below the city.

The work at this point, commenced on a small scale rather

*See "Municipal Government in Continental Europe," by Albert Shaw; Engineering News, Vol. XXXIV, p. 121; Engineering Record, Vol. XXXV, p. 5, and "Water Supply and Irrigation Papers of the U. S. Geological Survey" No. 3, by Geo. W. Rafter.

experimentally and as far back as 1868, has proved so satisfactory that the city has since increased the extent of the irrigation fields to some 2,000 acres, and has adopted a comprehensive scheme, now being executed at a cost of over \$16,000,000, which will dispose of all the city sewage by irrigation. What cannot be utilized at Gennevilliers will be carried beyond to a sandy tract of land near Acheres, about 10 miles below the city.

Here some 3,800 acres out of a total requirement of upwards of 8,700 have already been acquired, which will be reached by a large outfall sewer having a capacity of about 230 million gallons per day and involving a further lift of the sewage to a height of 118 feet.

The experience thus far accumulated establishes a large increase in the value of land in the neighborhood of the farms, which are not operated by the City of Paris, but are leased to agriculturists. There is a marked improvement in the health of the locality; the death rate, formerly 32 per thousand, having fallen to less than 25 per thousand.

It is found, too, that a large variety of garden produce may be profitably raised in this way, and that the use of sewage for irrigation neither interferes with the salubrity of the neighborhood, nor affects unfavorably the wholesomeness of the crops raised as food. The rough product of the Gennevilliers farms brings the farmers a return of from \$240 to \$800 per acre.

BERLIN.*

Berlin is a city of nearly 2,000,000 inhabitants within an area of about $24\frac{1}{2}$ square miles.

It is located on the river Spree, which here flows through a valley from three to four miles wide. Two-thirds of the total area of the city is found in this valley, and the average street level of so much of the city is only about 10 feet above the surface of the river.

The flow of the Spree is very sluggish in ordinary weather; in periods of excessive drought it is extremely so. The prevailing condition made an improved system of sewerage absolutely necessary. A scheme to intercept the sewage on either side of the river and, conveying it below, to discharge it after

* See Proceedings of the Institution of Civil Engineers, Vol. CIX; Engineering News, Vol. XXXVI, p. 139, and "Water Supply and Irrigation Papers of the U. S. Geological Survey" No. 3, by Geo. W. Rafter.

some treatment into the Spree, was abandoned, and in 1873 the City Council decided to employ sewage irrigation as the best method of disposal.

The carrying out of this plan has led to the development of the largest and perhaps the most successful sewage farm anywhere existing.

The topography of the city and the high level at which the ground water stands has made the method of collecting the sewage somewhat peculiar. It has been found expedient that each of the twelve drainage districts into which the city has been divided should have its own pumping station, whence the sewage is lifted to the sewage farms, located on the high ground to the north and south of the valley, the heights of which are some eighty feet and fifty feet respectively above the river.

The farm lands have been purchased and are owned by the city, and from a beginning in 1874 of 2,000 acres, now amount to upwards of 22,000 acres.

Of this area about 22 per cent. is taken up by parks, woods, gardens, roads and buildings, and the area actually farmed may be set down as about 17,500 acres, of which about 16,600 acres have been prepared by under-drainage. This is made necessary by the soil being less permeable than could be desired and resting at a depth of from $3\frac{1}{2}$ to 5 feet upon a bed of quite impervious material.

A portion of the farm lands, some 2,200 acres in 1890, is rented out to gardeners and small farmers, whose appreciation of the value of the irrigation is shown by their paying an annual rental for land duly prepared for irrigation \$21.50 per acre, whilst for unprepared land the rate is but \$8.80 per acre.

The total sewage disposed of during the year 1893-4 averaged 46 millions of gallons per day, which was delivered upon 11,542 acres, or about 4,000 gallons per acre per day, and was derived from about 1,600,000 population at the rate of about 28 gallons per head. The water consumption per head being but 18 gallons, the remaining ten gallons are due to rainfall and other sources.

Upwards of 400 acres are held in reserve as filtration areas, upon which to discharge excess of storm water in summer. These are arranged in plots of from 5 to 22 acres each, surrounded on all sides by embankments about 3 feet in height, and, under the name of tanks, serve in winter to receive the

sewage when the surface of the irrigation fields may be so frozen as to prevent filtration through them.

The effluent from the farms is purified to such degree that as a rule it passes off clear and transparent, and we are told that fish thrive in it.

The sanitary condition of the Berlin farms is reported as being very satisfactory, and the health of the people good, although a large number of them are from a class of petty delinquents, such as our tramps, whose habits of life are not favorable to health.

The general salubrity of the farms may be further inferred from the fact that four homes for convalescents, with two hundred and eighty-six beds in all, have been established on the farms, and are supplied with water by wells sunk on the spot.

A most interesting and important fact connected with the improved sewerage of Berlin is found in the greatly reduced death rate which has attended the development of the system.

In 1875, when but 57 houses were connected with the sewers, the annual death rate was 32.9 per 1,000; whilst in 1892 with 22,012 connections the rate was reduced to 20.2 per 1,000.

The entire cost of construction of this system has been, up to the present year—

For the collection system	\$14,125,000
For pumping plant and delivery of the sewage to the farms	4,850,000
Cost of the farm lands	4,350,000
Preparation of the land and farm plant..	3,300,000
	<u>\$26,625,000</u>

For the year 1893-94 the cost of working the system was—

For maintenance of the sewers and pumps and operating the same	\$ 337,000
Maintenance and working the farms	510,000
Interest on capital outlay, including sink- ing fund	1,046,000
	<u>\$1,893,000</u>

This outlay was met as follows:

Sewer tax on 22,091 house con- nections	\$732,000
Produce and rental of farms....	446,000
	<u>1,178,000</u>

MELBOURNE.*

The City of Melbourne, Australia, is just completing a comprehensive system of sewerage which, from the striking similarity of many of its prevailing conditions to those of Baltimore, is of particular interest.

The city proper, with an area of but 7.4 square miles and a population in 1890 of 76,500, forms part of a populous district which, within an area of 134 square miles, includes some six cities and an equal number each of towns, boroughs and shires, with an aggregate population of about 430,000 at the date named, of whom about 281,000 persons are resident upon 21 square miles.

The area dealt with by the system is intersected by the river Yarra and its tributaries, whose mouth is in the harbor at the head of Port Phillip Bay, and distant 34 miles in a direct line from the ocean.

The bay has an area of about 720 square miles, with an entrance from the ocean only two miles in width.

Within the heads or capes of the bay the sectional area increases so rapidly that, though the ocean tide rises some seven feet and gives a velocity through the heads of $6\frac{3}{4}$ miles per hour, the currents within the bay are very sluggish and, excepting as influenced by winds, are practically simple up and down movements, and are deemed utterly useless for carrying to the ocean the matter discharged into the bay, even with the aid of the flow of the river Yarra.

This presents such a condition as we find in our harbor and river at home, and the discharge of waste of all kinds, including the overflow of cesspools into the Yarra and the harbor, had produced in 1889 similar results to those we have experienced in our Jones' Falls and harbor, and the nuisance had become of such magnitude as to require abatement.

After much preliminary consideration, the distinguished civil engineer Mr. James Mansergh, M. I. C. E., was engaged to visit Melbourne and prepare a report on the sewerage of the city and the disposal of the sewage.

The report prepared by Mr. Mansergh is very full, and for

*See Report on the Sewerage and Sewage Disposal of the proposed Melbourne Metropolitan District, by James Mansergh, M. I. C. E., 1890, with subsequent Reports of the Chairman of the Melbourne and Metropolitan Board of Works.

us particularly instructive. He recognizes that storm water should be excluded from the new sewers as far as may be, though he provides for one-tenth of an inch per day of rainfall from the whole area. He states that after a long experience there are left but three methods of sewage disposal from which to select, depending on the varying situations and circumstances of the city or town to be dealt with. These are:

“1st. Discharge of the sewage in its natural untreated condition into the sea or a large tidal river.

“2nd. The removal of the suspended solids and a part of the dissolved impurities in the process of precipitation by means of chemical reagents; the discharge of the clarified liquid into the natural watercourses, and the disposal of the precipitate, either usefully or otherwise, upon land.

“3rd. Passing the sewage over land for the irrigation of growing crops and the filtration of the liquid through the subsoil.”

Mr. Mansergh found it clear to his mind that there was no point in Port Phillip Bay where the sewage could be discharged with impunity.

An examination and estimate confirmed the first impression that to discharge into the ocean involved a length and cost of outfall sewer quite prohibitory.

Chemical treatment was considered and its cost worked out, but was not found to be advantageous.

The plan recommended was for disposal of the sewage upon land; about 58 per cent. of the whole to be pumped against a head of 96 feet into an eastern outfall sewer and delivered on a sewage farm distant about 12 miles from the pumping station; the remaining 42 per cent. to be pumped against a head of 116 feet through a western outfall sewer to another sewage farm on the opposite or western shore of the bay, distant from its pumping station about $14\frac{1}{3}$ miles.

Mr. Mansergh estimated the cost of the works, developed to the extent required for a population of 509,000 in 1898, at a total (in our currency) of \$25,150,000, and disposing of a daily flow of sewage of 45,854,000 U. S. gallons, at an annual cost for operation and maintenance of \$841,000.

The scheme was planned to be adequate for the development and growth of the district as forecast for about 50

years when, in the year 1939, the population might be 1,680,000, and the sewage to be disposed of each day 151,167,000 U. S. gallons.

The estimated capital cost of the plant for such computed service was \$29,082,000, and the annual cost of operation and maintenance \$1,278,000.

The plan presented by Mr. Mansergh has been somewhat modified and its estimated cost reduced by the more detailed investigation of the engineer entrusted with the execution of the work. It is being carried out on a basis providing for the delivery of the whole of the sewage to but one sewage farm, for which upwards of 8,500 acres have already been acquired, and of which some 3,600 acres are under cultivation, mostly under lease from the city, with provision for an ultimate population of but 1,000,000 instead of 1,680,00, as figured by Mr. Mansergh.

The cost of the system as modified has been so much reduced that the estimated cost in 1898 for the service of 509,000 population is given at \$17,655,000, a reduction of \$7,495,000 from the original estimate of Mr. Mansergh.

We do not find any estimate of the ultimate cost of the revised system when extended for 1,000,000 population, but it is stated that the additions and extensions can be readily made as required without an undue proportion of additional cost.

The experience of Melbourne serves further to illustrate the great importance of a thorough and most careful revision of preliminary plans before undertaking the execution of such important and costly work.

INVESTIGATION OF THE PROBLEM.

The questions which your Commission is expected to report upon include the mode of collection of the sewage, the alignment, gradients and dimensions of the intercepting sewers, the amount of pumping involved, and are dominated by the all-important one of final disposal.

To aid in the determination of these questions and to arrive at an approximate estimate of the cost of constructing the necessary works, your Commission, in May, 1894, called to its aid as Consulting Engineer, Mr. Samuel M. Gray, M.

Am. Soc. C. E., of Providence, R. I., and in April, 1895, secured in the same capacity the services of Mr. Rudolph Hering, M. Am. Soc. C. E., of New York. Both are men of eminence in their profession and are recognized experts in sewerage work.

The Commission also engaged in September, 1895, as its Principal Assistant Engineer, Mr. Kenneth Allen, M. Am. Soc. C. E., who has conducted, in the office of the Commission, and with the aid of assistants in the office or in the field, as from time to time required, all the investigations called for by the Commission, whether for its own information or to supply additional data needed by the Consulting Engineers. Amongst other duties it has devolved upon this officer to investigate questions regarding the sufficiency of the existing storm-water drains, with the extensions and additions required therefor. His report to the Commission on this subject will be found in Appendix B to this Report.

The Consulting Engineers were each requested to consider the sewerage of the city in all its bearings, and to advise the Commission as to the best method in his judgment of collecting and disposing of the sewage and storm water of the city, to meet present requirements and to be capable of expansion and development, as exigencies of a growing city and an increasing population may make necessary. They were requested to give reasons for the conclusions at which they might arrive, with drawings and plans of the schemes they might present, together with estimates of the cost of carrying the same into effect.

The making of surveys and collection of further data, as called for from time to time by the Consulting Engineers, with the making of the necessary maps to elucidate them, has been followed on the part of these gentlemen by their consideration and investigation of the various problems involved, and we now have before us their full report and recommendations, which are submitted herewith—Appendix C.

It was understood between your Commission and the Consulting Engineers that, whilst they were free to consult and work together as might best suit the convenience of all concerned, the conclusions at which they might arrive were to be their individual opinions, which might or might not be

identical. As the result of their investigations the views of the Consulting Engineers are in such complete accord that they have been able to make a joint report and unite in the plans, estimates and recommendations, with which it is concluded.

The Engineers, after discussing fully the existing conditions of the problem, arrive at the conclusion that the adoption of the separate system is more urgently required here than in any other city of the United States, not already provided with a modern system of sewers, and find that an allowance of 150 gallons per head of population, per day, is an amount both reasonable and sufficient, not only at the present time, but should be adequate for the future estimated population of one million.

They then take up three different methods of disposing of this amount of sewage, together with a fourth plan, a combination of two of the methods.

These will hereafter be referred to respectively as Projects A, B, C, and D.

First. Project A.

This disposes of the sewage through dilution, by discharging it into Chesapeake Bay, off North Point, at a distance from the shore line of from 5,000 feet to 12,500 feet.

Second. Project B.

This employs the process of chemical precipitation. Under it the sewage is treated by a special plant at or near Colgate Creek, on the north side of the Patapsco, the effluent being discharged temporarily at that point and eventually at North Point.

Third. Project C.

This plan treats the sewage by filtration upon land, of which quantity and quality sufficient and suitable have been found in Anne Arundel county, and will discharge the purified effluent into streams emptying into the Patapsco or into Magothy river.

Fourth. Project D.

This combines with an ultimate use of Project C a temporary employment of chemical precipitation by a plant located

on the shore of Patapsco river near Ferry Point, discharging the outfall into the river. The only object of this is to defer any outlay for the heavy work required, even for the partial development of the outfall under Project C, until such time as the growth of the population connected with the system makes necessary the construction of the entire plant of the filtration system under Project C.

Some portions of the works required by the several projects, such as the intercepting sewers, the pumping stations, and, in the case of Project A, the main outfall sewer, will have to be built at once; whilst other portions, such as the pumping machinery, an additional outlet pipe into Chesapeake Bay, the chemical precipitation plant, the siphon under the Patapsco at Ferry Point, the force mains to Anne Arundel filtration fields, and these fields themselves, may all be constructed, developed or acquired gradually, somewhat in proportion to the increase of population connected with the sewers.

The Consulting Engineers have, therefore, estimated the cost of the several projects in two forms:

(a). For the works necessary to give proper disposal to the sewage of the present population, or such portion of it as can be brought into connection with the system by the time the system is ready to receive the sewage, and for a few years thereafter. They assume that the population thus to be served will not for some time exceed one-third of the ultimate population of one million, or say, 330,000.

(b). For the works required to give full and adequate disposal to the sewage for the whole city and its assumed future population of one million.

Estimates have also been submitted of the annual cost of operation, depreciation and repairs.

Consideration of interest and sinking fund is omitted for the purpose of a first comparison in the following table:

COST OF THE SEVERAL PROJECTS AS PRESENTED
BY THE CONSULTING ENGINEERS.

Interest and Sinking Fund not here included.

PROJECT.	a—First Installation. 330,000 Population.		b—Completed Works. 1,000,000 Population.	
	Cost of Construc- tion.	Annual cost of Opera- tion, Depre- ciation and Repairs.	Cost of Construc- tion.	Annual cost of Opera- tion, Depre- ciation and Repairs.
A—Dilution.....	\$3,880,167	\$58,491.91	\$5,129,167	\$85,289.91
B—Precipitation.....	2,962,000	165,894.02	5,503,000	444,871.99
C—Filtration.....	5,741,007	173,111.65	12,171,803	426,171.62
D—Filtration with temporary precipitation	3,019,012	180,594.34	12,550,891	426,171.62

The relative cost of constructing these several projects and of operating them respectively, taking Project A at 100, and without consideration of interest and sinking fund, is shown to be as follows:

PROJECT.	a—First Installation.		b—Works Completed.	
	Construc- tion.	Operation.	Construc- tion.	Operation.
A—Dilution.....	100	100	100	100
B—Precipitation.....	76	283	107	521
C—Filtration.....	148	296	237	500
D—Filtration with temporary precipitation	78	309	244	500

It thus appears that, whilst Project B costs 24 per cent. less than A for first installation and but 7 per cent. more than A for the completed works, its annual operation (neglecting interest) will exceed that of A 183 per cent. at the outstart and 421 per cent. at a later period.

As compared with C, we find the latter costs 48 per cent. more for first installation and 137 per cent. more eventually; whilst its annual operation (neglecting interest) costs 196 per cent. more at the outstart and 400 per cent. more when completed.

As compared with D, we find the latter to cost 22 per cent. less than A for first installation, but 144 per cent. more for the completed works; whilst for its annual operation (still omitting interest), we find it to cost 209 per cent. more at the outstart and 400 per cent. more when all works are completed.

It would thus appear that on the estimates furnished, if cost of construction and operation is to be considered, Project A, Dilution, with discharge into Chesapeake Bay, is much the most economical of the several schemes.

The Report of the Consulting Engineers, nevertheless, does not recommend Project A, but does recommend disposal of the sewage by filtration upon the sandy territory in Anne Arundel county, Project C, as the best solution of the problem for all time.

It now devolves upon your Commission, with the aid which the professional skill and experience of its Consulting Engineers has brought to its assistance, to present its own study of the subject, together with its conclusions and recommendations.

RELATIVE MERITS OF THE VARIOUS METHODS OF DISPOSAL MORE OR LESS SUITABLE UNDER OUR EXISTING CONDITIONS.

It has been shown that there are practically but three methods of sewage disposal known to the science of the day. These are dilution, chemical precipitation, and filtration through the soil.

The applicability of each of these to the conditions existing at Baltimore will now be considered.

DILUTION.

Patapsco River.

It needs no further argument to show that there is neither sufficient fluvial nor tidal current in the Patapsco river to dilute and dispose of the sewage by discharge into the river.

We are told by the Consulting Engineers that a minimum flow of 3 cubic feet per second is essential to dispose of the sewage of 1,000 persons, whilst their investigations show that the minimum fluvial flow of the Patapsco may be taken at 111 cubic feet per second. On these assumptions they further indicate that the Patapsco might receive without becoming offensive the sewage of not more than 37,000 persons, whilst we have over 500,000 to provide for at present, and more in the future.

Back River.

A discharge into Back River has been considered, but found quite inadmissible. Whilst the whole of the sewage might be conveyed, and four-fifths of it by gravity, to a point on this arm of the bay, distant from the eastern limits of the city about seven miles, yet the result would be to make a perpetual nuisance of this inlet, now a popular and rapidly improving pleasure resort. There is no current to sweep out the offensive matter into the bay, so that it will collect if discharged there, and convert Back River into a large cess-pool, to the ruin of all the interests which now find there both pleasure and profit.

Chesapeake Bay.

The only other possibility of crude disposal is a discharge into Chesapeake Bay, off North Point, or in that vicinity.

This outfall was recommended by Mr. Charles H. Latrobe, M. Am. Soc. C. E., in his report to the Mayor and City Council in 1881.

It has now again been investigated after making the necessary surveys, and is reported upon by the Consulting Engineers, being Project A, already referred to.

It is found that after lifting through 52 feet the low-level sewage, which will ultimately not exceed one-fourth of the total, the whole volume may be conveyed by gravity to an outfall point on the shore of the bay north and east of North Point, and distant about 30 miles from the head of the bay, where empties the Susquehanna river.

This river drains a territory of some 27,000 square miles,

and has an ordinary dry weather flow estimated at from 15,000 to 35,000 cubic feet per second.

By a gauging made in the summer of 1895, by Mr. James H. Harlow, M. Am. Soc. C. E., at Marietta, a point on the river some 44 miles above its mouth, and during a stage of water lower than any noted by records kept continuously at Harrisburg, Pennsylvania, since 1803, he estimates the flow at the State line, some 14 miles above the mouth of the river, to be 6,500 cubic feet per second.

The width of the bay at the sewer outfall is about 9 miles, and the nearest shore line to the southward is found at Bodkin Point, distant over five miles, with the channel of the Patapsco river intervening. See Plate II.

The depth of water on the line of the sewer outfall pipes of Project A is only 6 feet at a distance of one quarter of a mile from the shore, 12 feet at a distance of half a mile and 14 feet at seven-eighths of a mile, increasing to 16 feet at a distance of a mile and a half and to 18 feet at about 2 miles from the shore.

Whilst the principal channel is along the eastern shore of the bay, where from 30 to 40 feet of water may be found, yet the less important channel into which the sewage would be discharged by Project A is believed to afford sufficient current to effect thoroughly and completely the dilution of all the sewage which can be there delivered by the City of Baltimore.

This current, which was investigated by Gen. Wm. P. Craighill, Corps of Engineers, U. S. A., when in charge of the approaches to the harbor of Baltimore, and of which the results were kindly placed at the service of your Commission, was quite sufficient to cause some trouble by the silt which it brought down and deposited in the Brewerton Channel extended.

Its evil effects were remedied by the excavation of the Craighill Channel, and the Cut-off Channel, the latter on a line approximately parallel to the direction of the current, somewhat deflected to the eastward by that of the Patapsco.

As there are no exposed shores on which the crude sewage might impinge, it does not seem possible that there could be any offense to the human senses by its discharge into the waters of the bay under Project A.

OYSTER INTERESTS.

That no aspect of the subject shall, however, escape due attention, it is proper here to consider whether a discharge at North Point can in any way injuriously affect the oyster interests, which are of paramount commercial importance to the State of Maryland.

It has been stated by Mr. Charles H. Stevenson* that "the water area of Maryland is the greatest oyster producing region in the world, and the output of the industry is fully equal in value to one-sixth of the product of all the fisheries of the United States combined, giving employment to one-fifth of the persons engaged therein." He further states that in 1892 Maryland produced 11,632,730 bushels of oysters, with a value of \$5,866,120, being over 39 per cent. of the entire oyster production of the United States and about one-third of that of the entire world.

So important an industry should not only be carefully guarded against actual injury, but every precaution should be taken that there need be no apprehension whatever of damage thereto.

The oyster grounds of Maryland at one time extended from the Virginia State line to the Susquehanna river, but we are told that "rarely in recent years have any of the oystermen resorted to the reefs situated about Pool's Island and north of Swan Point," which latter is on the eastern shore of the bay directly opposite North Point.

That few are now taken there is attributed by Mr. Stevenson not to over-fishing, as popularly supposed, but to the change in the quantity of fresh water flowing into the bay and the increased volume of the spring freshets.

It has been stated by a gentleman engaged in the oyster traffic that the great freshet of 1889 in the Susquehanna completely destroyed the oysters on the "lumps" in that part of the bay, and although there has been a partial recovery, it is understood that the beds have been but little worked since.

Until recent years the oyster has been free from suspicion as a vehicle for the transmission of communicable disease. In the report of the State Board of Health of the State of

* The Oyster Industry of Maryland, by Charles H. Stevenson, pp. 203-297 of Bulletin of U. S. Fish Commission, 1892.

Connecticut for the year 1894 we have an account of an outbreak of typhoid fever which occurred at Wesleyan University, Middletown, Connecticut, in October, 1893, and which was most carefully and with great precision traced to its cause. It was established that out of 100 students who on the same night at certain club suppers partook of raw oysters, 25 were taken with typhoid fever, whilst of those who ate the oysters cooked none suffered.

These oysters were traced to a particular lot which, taken from the deeper waters of Long Island Sound, were deposited for a day or two in a fresh water creek at Fair Haven to "fatten," and had been placed as close as 256 feet from the outlet of a private sewer which drained a house in which were two persons suffering from typhoid fever.

The notoriety attending this case has led to much investigation both at home and abroad. The State Board of Health of Connecticut discusses it in its reports for 1894 and 1895. In the Twenty-fourth Annual Report of the Local Government Board (England and Wales), being entitled "Report and Papers on the Cultivation and Storage of Oysters and certain other Molluscs in relation to the Occurrence of Disease in Man," submitted by Dr. R. T. Thorn, we find an extended reference to and discussion of this case, together with a detailed inquiry conducted by Dr. H. T. Bulstrode, into all the oyster beds surrounding the English and Welsh coasts.

We find also in the Proceedings of the Académie de Médecine of Paris a memoir by Dr. Chantemesse upon the relation of oysters and typhoid fever with reference to the Wesleyan case.

The subject has been receiving, altogether, much attention recently in scientific circles. A paper relating to it was submitted by Prof. R. Boyce and discussed at the Liverpool meeting of the British Association in September last. It has also been discussed elsewhere * by Profs. T. E. Thorpe and W. A. Herdman. The last-named cites many points which he believes have been fully demonstrated. Amongst others, the following have application to the matter we are considering:

"The beneficial effect of free change of water round the oysters."

* *Nature*, Vol. 55, pp. 105-107 and 293.

“The fact that the typhoid bacillus does not flourish in sea water. There is no initial or subsequent multiplication; on the contrary, it seems to die off very rapidly as time increases after inoculation.”

“The fact that the typhoid bacillus does not multiply in the stomach or tissues of the oyster.”

“The possibility of getting rid of bacterial infection by placing the oyster in a stream of running water. There is a great diminution or total disappearance of the typhoid bacillus under these circumstances in from one to seven days.”

The conclusions at which the several investigators seem to arrive are, that the oyster is liable to temporary contamination by exposure to contact with sewage, and that either the use of such oysters should be interdicted or, in order to render them safe for use in the raw state, they should be given a cleansing by transferring them for some time to a current of water free from pollution.

Dr. Thorn in his report further states: “So also the dilution of the sewage is not infrequently very considerable; at times, indeed, so considerable that the chances of sewage contamination hardly call for notice.”

Again he says: “Every skilled observer whose investigations have gone to show that certain oysters have served as the medium for conveying disease to man, has admitted that the risk is by no means a great one; several speak of such occurrences as distinctly rare; and certain observations which have been recently made have afforded further data in explanation of this comparative rarity.”

Your Commission has been advised by an acknowledged authority on all that relates to the biology of the oyster that a discharge of the sewage of the city, as here contemplated, would be beneficial rather than injurious to the oysters themselves.

We must here note, however, that the same authority calls our attention strongly to the possibility that some noxious germs or bacteria derived from the sewage and not yet digested by the oyster may be conveyed with it in the raw state to the human stomach and there give rise to disease.

This is undoubtedly possible, and the experience at Middletown, Conn., already referred to, is a very notable case in point. But we are not bound to take our oysters from the

immediate wash of the sewage, even if any are to be found about the point of probable discharge, which, from the best information obtainable, seems doubtful. It may even be deemed wise for the City to acquire the exclusive right to take oysters within a certain defined range from the outfall, to appropriate all so taken to planting purposes, and transfer them to other places where, in water free from pollution, a period of from eight to twenty days, according to different observers, suffices to purge the oysters of all trace of the noxious bacteria. As the distance from the point of outfall increases, the conditions become the same as prevail in scores, we might say in hundreds, of places without any known damage having resulted therefrom.

In the "Report of the Oyster Commission of the State of Maryland," made in 1894, we find a statement from Ingersoll, "Report on the Oyster Industry of the United States," giving the quantities of Chesapeake oysters planted annually at Wellfleet, Boston, Salem and Newburyport, Mass.; at Portsmouth and other cities of New Hampshire; at Portland, Maine; in Buzzard's Bay and Narragansett Bay, at New Haven, Conn., in New York Bay, and on the west shore of Delaware Bay.

Many of these very plantings, to say nothing of such natural beds as exist in the same localities, are exposed with entire impunity, so far as known, to the more or less diluted sewage of the adjacent cities. This must be the case at Newburyport and Portsmouth, at Boston and Salem, and everywhere along the shores of Massachusetts Bay. It must be the case in Narragansett Bay, where all the sewage of Providence and Fall River is discharged at its head. The same occurs in Long Island Sound, into which is received all the sewage of Bridgeport, New Haven, Springfield, Norwich, New London and scores of other cities or towns. In New York Bay and Raritan Bay all the oysters are taken from waters into which is poured the sewage of New York, Brooklyn, Jersey City, Hoboken, Paterson, Newark and innumerable smaller places, whilst the densely populated shores of Staten Island and New Jersey contribute their share, without there being entertained any idea of contamination and no experience of evil.

The oysters of Delaware Bay, a very much smaller body of

water than the Chesapeake, are exposed to all the damage which can be inflicted by the sewage of Wilmington, Philadelphia, Trenton and the cities and towns which lie on the banks of the Delaware, Schuylkill and Lehigh rivers, and yet we hear of no disease caused thereby.

And now to come to our own waters, we already have carried through our bay all the sewage from the cities and towns along the Susquehanna river. To this is added through the Patapsco the filth from our own city, and through the Potomac the sewage outpour from Washington, Cumberland and intermediate towns. Annapolis contributes something, and smaller places along the bay their share; whilst still lower down we reach the finest oysters subjected to exposure from the output of Norfolk, Portsmouth, Richmond, etc., and yet no evidence of disease resulting from their use.

It would seem, therefore, as the result of general experience that in the Chesapeake Bay, where the dispersion of the sewage will take place in an immense body of water in constant movement under the influence of winds, tides and fluvial currents, there need be no apprehension of evil, either to the oysters or to those who use them.

CHEMICAL PRECIPITATION.

While this method of disposal, Project B, has been investigated and found feasible, though not recommended by the Consulting Engineers who have reported and estimated its cost, we may dismiss it from present consideration by pointing out that, though its adoption would, according to the table, p. 49, save an immediate outlay of \$918,000 in the cost of first installation, it would be at the price of \$107,402.11 per annum for increased cost of operation. This sum at 4 per cent. represents the annual interest and sinking fund accumulation on a capital outlay of \$2,685,000, or nearly three times the amount of first cost which its adoption would save, so that economy in first cost presents no inducement for availing of it, nor can there be any reason to resort to it unless crude discharge into the bay should prove to be objectionable.

FILTRATION.

This method of disposal for the sewage of Baltimore, Project C, has been very fully considered and reported upon by the Consulting Engineers together with estimates of cost.

The method is an ideal one, and the farm lands in Anne Arundel County on which outfall would be made are peculiarly well adapted for such treatment, the soil being sandy, porous and naturally well underdrained. The soil and crops would have the benefit of the manurial value of the sewage, whilst the means of irrigation, always at hand, would insure returns to the farmer, even in seasons of greatest drought. The effluent water after having done duty on the farms or, when not required there, after passing through the reserved filter beds, would drain into the Patapsco or, in the more distant future, into the Magothy, as clear and limpid as when drawn from the pipes of our water supply.

The farms after being brought under treatment would be leased, as is the case in Paris, to farmers and market gardeners at rentals increasing as the beneficial effects of sewage irrigation became manifest and more widely known. A portion would probably always be operated and farmed by the City in advance of outside demand and could be worked by the labor of the City's pauper establishment, which would in all probability be eventually located there.

Although it might be difficult to insure as effective an administration as exists under the military discipline which prevails on the Berlin farms, there is no reason to doubt that, properly managed, it could be made a model establishment, and perhaps a finer exemplar of the system than any now in existence.

This is the system, Project C, recommended for adoption by the Consulting Engineers.

A serious drawback to the adoption of this scheme is its much greater relative cost, both for its establishment and subsequent working. To reach the outfall fields involves the crossing, or piercing by one or more tunnels, of an intervening ridge, which attains an altitude above mean tide of about 155 feet, and requires the pumping of about two-thirds of all the sewage against a head of 128 feet. The remaining third would reach the outfall by gravity.

As Project D, making use temporarily of chemical precipitation, has value only as an expedient for postponing for a time the larger expenditures of Project C, it need not be discussed here further than to recognize its availability, though not perhaps its expediency, should Project C be deemed the best plan for adoption.

DISTRICT AND LATERAL SEWERS.

RETICULATION SYSTEM.

Before making further comparison of the projects submitted, it is necessary to call attention to the fact that the tabulated estimates made by the Consulting Engineers are only for the cost of intercepting and disposing of the sewage. They mention this on p. 196 of their report, and state their reasons for having made no attempt to include designs and estimates of cost for the local or district sewers. Your Commission recognizes the propriety of their conclusion. The work of laying out such local, district and lateral sewers is a very simple matter in competent hands; but it cannot be done intelligently until it be first known where the sewage is to go. To have laid out all the lateral sewers on their proper lines to serve each of the projects considered would have greatly and unnecessarily increased the cost of the work of your Commission. In fact, as the streets in the annexed district have not yet been laid out and their grades fixed, it would be simply impossible at the present time to determine upon the laterals to serve that district. Nevertheless the laterals, which may be termed the reticulation system, must be well under way before any sewage will reach the disposal system, and as Baltimore, unlike most other cities with which its plans will be compared, has no such reticulation already in existence, it must be constructed simultaneously with the disposal and outfall system. It will be under charge of the same officers, and will have to be paid for at the same time. It is therefore in the case before us an integral part of the system, and its estimated cost must be included at the outstart in the cost of the works as a whole.

The Commission has therefore caused to be made an estimate of the cost of such reticulation. It is at best but

roughly approximate, but is believed to be large enough to cover the probable cost. This is found to be, for the first installation with connections for the service of say 330,000 persons, \$2,032,500. Ultimately, when extended throughout the entire city, and serving a population of one million, its cost will probably reach \$5,280,000.

One or other of these sums is therefore to be added to each of the estimates of the Consulting Engineers in order to learn the actual amount of money to be expended on the work.

RELATIVE COST OF THE SEVERAL SCHEMES.

Of the four projects A, B, C and D, we have C, the filtration system, recommended by the Consulting Engineers as the best, irrespective of cost. It is the best because with it the character of the effluent is always under control, so long as the quantity of land available for its purposes is only limited by the demand of perfect filtration, whilst in addition and incidental thereto is the application of the sewage to the irrigation and fertilization of the land.

Your Commission recognizes all this, and is satisfied that all the land necessary for filtering the sewage of a larger population than Baltimore is likely to attain, may be had on reasonable terms in Anne Arundel County; yet it cannot disregard the matter of cost.

If another project will accomplish the purpose thoroughly well from a practical point of view, and at less cost, there can be no warrant for increasing the burthen of our already heavily charged tax-payers in order that the system adopted shall be not only efficient but one of ideal perfection.

We have shown, p. 57, that Project B presents no inducement for its particular consideration unless Project A is found to be unavailable. Project D also needs no discussion except as a temporary modification of Project C. We will therefore confine our immediate attention to the relative merits of Projects A and C.

COST OF PROJECTS A AND C COMPARED.

The following table shows the outlay of capital required to construct each of these schemes; also the difference in their cost:

COMPARISON OF CAPITAL OUTLAY FOR CONSTRUCTION OF
SYSTEMS OF SEWAGE DISPOSAL BY PROJECT A INTO
CHESAPEAKE BAY, AND BY PROJECT C ON LAND IN ANNE
ARUNDEL COUNTY.

	a. First installation. 330,000 in connection.		b. Completed works. 1,000,000 in connection.	
	A. Dilution.	C. Filtration.	A. Dilution.	C. Filtration.
Estimate of Consulting Engineers for intercepting and disposal of sewage.....	\$3,880,167	\$5,741,007	\$5,129,167	\$12,171,803
Estimate of Commission for Reticulation System.....	<u>2,032,500</u>	<u>2,032,500</u>	<u>5,280,000</u>	<u>5,280,000</u>
Cost of first installation of Filtration—Project C.....		\$7,773,507		
Cost of first installation of Dilution—Project A.....		<u>5,912,667</u>		
Cost of completed works of Filtration—Project C.....				\$17,451,803
Cost of completed works of Dilution—Project A.....				<u>10,409,167</u>
Difference of first cost in favor of Dilution—Project A—a..		\$1,860,840		
Difference of final cost in favor of Dilution—Project A—b..				
				\$7,042,636

It is seen that at the first installation of the works \$1,860,840 more will have been expended upon the Anne Arundel Co. works, Project C, than required for the Chesapeake Bay works, Project A; and that at their completion the Anne Arundel Co. works, Project C, will have cost more by \$7,042,636 than required for completion of those under the Chesapeake Bay delivery scheme, Project A.

It is well here to state that, through incorrect information supplied to the Consulting Engineers, the value of the 1,800 acres, required for the first installation of the filtration plant, Project C, has been underestimated. These, being the lands first required for use, are nearest to the city and are much more valuable than those required for the future development of the system.

Your Commission, after having had these lands examined by an expert, is satisfied that their value is probably double that of the estimate. The cost of the first installation of Project C should therefore be increased by \$94,200. No such increase is necessary in the estimate for the fully completed works of Project C, as the average price allowed for the whole 5,384 acres is deemed ample.

With this correction the difference in cost of first installation becomes \$1,955,040 in favor of Project A instead of \$1,860,840 as shown by the preceding table. For the full completion of the works the difference in favor of Project A remains, as by the table, \$7,042,636.

COMPARISON OF ANNUAL COST OF MAINTENANCE AND OPERATION OF SYSTEMS OF SEWAGE DISPOSAL BY PROJECT A INTO CHESAPEAKE BAY, AND BY PROJECT C ON LAND IN ANNE ARUNDEL COUNTY.

	a. First installation. 330,000 population in connection.		b. Completed works. 1,000,000 population in connection.	
	A. Dilution.	C. Filtration.	A. Dilution.	C. Filtration.
	Annual Cost	Annual Cost	Annual Cost	Annual Cost
Maintenance and operation as per estimate of Engineers' Report.....	\$16,215.55	\$86,760.25	\$29,463.55	\$237,510.00
Depreciation and renewals as per estimate of Engineers' Report.....	42,276.36	90,319.40	55,826.36	200,029.62
Depreciation and maintenance of reticulation system, not estimated by Consulting Engineers	20,325.00	20,325.00	52,800.00	52,800.00
Annual interest on capital cost of works, together with annual payment to sinking fund to extinguish cost in 50 years—money at 3½ per cent.....	155,206.68	229,640.28	205,166.68	486,872.12
Total annual cost of operating. (Carried forward).....	\$234,023.59	\$427,044.93	\$343,256.59	\$977,211.74

COMPARISON OF ANNUAL COST OF MAINTENANCE, ETC.—*Cont.*

PROJECT.	a. First installation. 330,000 population in connection.		b. Completed works. 1,000,000 population in connection.	
	A. Dilution.	C. Filtration.	A. Dilution.	C. Filtration.
(Brought forward)	Annual Cost \$234,023.59	Annual Cost \$427,044.93	Annual Cost \$343,256.59	Annual Cost \$977,211.74
Interest on cost of land and other charges here included, assumed in Report of Engin- eers to be met by sales of crops and therefore here deducted		3,968.00		11,368.00
Annual cost to the taxpayers of first installation of Pro- ject C		\$423,076.93		
Annual cost to the taxpayers of first installation of Pro- ject A		234,023.59		
Annual cost to the taxpayers on final completion of Pro- ject C				\$965,843.74
Annual cost to the taxpayers on final completion of Pro- ject A				343,256.59
Annual saving to taxpayers by adoption of Project A, rather than Project C, at first installation		\$189,053.34		
Annual saving to taxpayers by adoption of Project A, rather than Project C, at final com- pletion of the works				\$622,587.15

The above table shows the annual cost of the two Projects A and C, and their relative economy. It is not thought necessary to correct the item of interest on capital outlay for first installation of Project C, as the difference due to the deficient estimate of cost of land, before referred to, is relatively very small.

It will be seen, therefore, that the adoption of Project A will result in an annual saving to the taxpayers of \$189,053.34 when the system is first set to work, and of \$622,587.15 annually when completed for one million population, as compared with the estimated annual charges for Project C, serving the same number of people.

To make these differences more clearly manifest, the cost of the several projects for which the Consulting Engineers have estimated are presented in graphic form on Plate IV.

It would seem from the relative cost of Projects A and C that, of the two, A should be selected as the one most advantageous to the interests of Baltimore; provided its disposal of the sewage is in every way applicable, and without offense, as the Consulting Engineers tell us in their report (page 198) is the case with any of the methods considered by them.

INVESTIGATION OF THE CURRENTS OF THE CHESAPEAKE BAY OFF NORTH POINT.

Whilst entertaining no doubt of the entire sufficiency of the waters of the bay to effect the full and rapid dilution of the sewage, it has seemed proper to the Commission before recommending the dilution project to secure all information obtainable bearing on the subject. With this view a consultation was had with Major N. H. Hutton, Engineer of the Harbor Board, whose twenty years or more of continuous service in connection with the river and harbor has brought him a large experience.

This conference confirmed the information in possession of the Commission, that for many years no current observations had been made near the point of proposed sewage outfall. The general action of the tides and currents was known and their relation to the maintenance of the ship channel well understood, but not so the drift of the currents with reference to the adjacent shore, and the result of the consultation determined the conclusion that it would be wise, before making recommendations, to ascertain by an investigation of the local currents their probable action upon the distribution of the sewage.

That this examination should not have already been called for by the Consulting Engineers is probably due to the fact that they were disposed to save the city a somewhat tedious and costly series of observations, unnecessary and avoidable in view of the entirely different system of disposal which they were prepared to recommend.

When, however, the Commission found the much less costly dilution project pressing upon its attention, it deemed itself

fully warranted in suspending its conclusions and, undeterred by the expense, quite justified in undertaking such an investigation of the currents into which the sewage would be discharged as would give a full assurance of the effects to be realized.

With this object it was determined by the Commission to obtain, if possible, the aid and advice of General Wm. P. Craighill, U. S. A., (retired), who was for so many years the officer of the Corps of Engineers, U. S. A., in charge of the improvement of the channels of the bay and river approaches to Baltimore.

It was felt that the knowledge and experience of this engineer, in regard to the currents and regimen of the portion of the bay affecting the questions before the Commission, would not only enable it to arrive more readily at positive results in regard to the sufficiency of these currents for the complete dilution and dispersion of the sewage; but it was also felt that his conclusions in this regard, whatever they might be, would carry great weight with our fellow-citizens, to whom his distinguished professional ability is so well known and by whom it has always been so highly regarded.

To the application made to him for his services, General Craighill replied that he would do his best for the interest of Baltimore in this case, as he had in previous ones.

After consultation with General Craighill it was concluded that the Commission would defer making current observations until the result of certain work of a similar character just then being undertaken by the U. S. Coast and Geodetic Survey might be learned.

By the courtesy of General W. W. Duffield, Superintendent of the U. S. Coast and Geodetic Survey, Lieut. E. H. Tillman, U. S. Navy, commanding Coast Survey Schooner "Matchless," then engaged in hydrographic work in Chesapeake Bay, was authorized to furnish for the use of this Commission such notes and data obtained by him as might prove of service to the work we had in hand, and to the cordial co-operation of this officer the Commission is indebted for some interesting and valuable observations.

A study of these developed the existence of currents about the proposed point of discharge of the sewage under Project A less favorable than had been anticipated, and, in Lieut. Till-

man's view, as in our own, seemed to indicate that a point two miles northeast of such proposed point of discharge, whilst not more distant from the shore, which trends in the same general direction, was likely to be in every way more satisfactory, as placing the discharge so much further to the east would tend to insure its passing down with the ebb tide to the eastward of the shoal lying immediately east of the Front Range Light of the Craighill Channel, and would expose it less to the flood tide, which makes up strongly along the North Point shore.

As Lieut. Tillman's duties were about to take him to another part of the bay, the Commission determined in consultation with General Craighill to undertake for itself a series of float observations for the purpose of determining the currents at and about this suggested point of discharge.

A suitable schooner, the "Ella Worden," of some thirty-five tons, with cabin accommodations for the observers, was accordingly chartered, and reported for duty on May 25th, 1897.

Taking on board the observers with the necessary stores and a supply of floats, she dropped down the same day to an anchorage about one mile to the eastward of the Rear Range Light of the Craighill Channel.

Here she was joined by the steam launch "Inspector," borrowed from the city's Quarantine Service. With this equipment, observations were commenced and continued for upwards of four weeks. The first work was the establishment of a number of points or stations on a line nearly due east of the Rear Range Light of the Craighill Channel. These were marked by poles driven into the muddy bottom at distances from the Rear Range Light of about 1 mile for station A; $1\frac{1}{2}$ miles for station B; 2 miles for station C; $2\frac{1}{2}$ miles for station K; 3 miles for station E; and $3\frac{1}{2}$ miles for station F. Plate VIII.

Owing to the general trend of the shore to the northeast, the distances from the shore of the more distant stations C, K, E and F were only from $1\frac{1}{2}$ miles to $2\frac{1}{2}$ miles.

The method adopted at the outset was, after establishing a tide-gauge at the Rear Range Light of the Craighill Channel, to set adrift at an early hour every morning a series of numbered floats from the several established points, the

changing positions of which under the influence of the tides and currents were duly noted.

This method was subsequently modified by starting floats hourly, and in some instances half-hourly, from one and the same point, marked K on the plan.

This point was selected in preference to others east or west of it as probably best suited for the discharge of the sewage, because, with deeper water and distance from shore about the same as in the case estimated on by the Consulting Engineers (Project A), although with a lengthening of the land conduit about $1\frac{1}{4}$ miles, an amount of easting was attained which would bring the outfall where, under the action of the flood tide, none of the output is likely to reach the shore without undergoing great dilution, and where, under the influence of the ebb, the tendency will be to carry the discharge to the eastward of the Front Range Light of the Craighill Channel, thus exposing it less to the action of the succeeding flood, which our observations show makes strongly to the westward.

The floats were sticks of yellow pine two inches square in section and from seven feet to eight and a half feet in length, loaded with cast iron washers secured by a wire passing through a hole drilled near the end of the stick so as to float vertically. They were designated by colored flags twelve inches square consecutively numbered and mounted on light iron rods inserted into the axis of the stick at its upper end.

After starting the floats the observer and his assistant followed them on the steam launch, observing their drift, locating with a sextant their positions from time to time, with reference to fixed landmarks and duly recording the observations.

The notes thus taken were returned to the office and, being there plotted on a chart of the bay, have served to indicate the influences to which the sewage would be exposed if discharged at the starting points of the several floats, and of the extent of the diffusion of the sewage in a given time.

The inability of the launch "Inspector" to keep at sea in much of the weather experienced during the period of our observations made it often impossible to follow the floats in their very divergent drift under the varying conditions of the

tide, and thus many of them were lost to observation, even before they passed south of the line X—Y as shown on the chart (Plates VIII and IX), beyond which there was no possibility of following them with the facilities available. That some few observations are recorded and plotted south of this line is due partly to the valuable assistance of Lieut. Tillman, U. S. N., who kindly took note of such floats as passed within range of his vessel, and to observations occasionally made from the Harbor Board's tug "Baltimore," which was frequently loaned to the service of your Commission for trips of inspection during the continuance of the work.

The floats lost to observation by inability to follow them on one day or by reason of nightfall interfering, were always sought and sometimes recovered on the following day, or were later discovered grounded on the shoals. Those not found are believed to have passed below the line X—Y, and to have passed down with the general current of the ebb tides.

Whilst the float observations are less complete and therefore less satisfactory than might have been the case had all the requirements been known in advance; had the craft employed been better able to cope with the prevailing weather conditions of the bay, and had the observers been sufficiently numerous to follow the floats throughout their entire course, say as far as Sandy Point, yet enough has been developed to indicate fairly well the action of the tidal currents and their probable effect on the sewage discharge, together with the amount of dilution that may be safely relied upon even before the diluted sewage on its way to the sea passes the line which limited the observations.

Plates VIII and IX present upon a chart of the bay a trace of the course of all floats set out from the several stations, with the last observed position of each.

From a study of these it has been found possible to construct diagrams which afford indication of the degree of dilution which the sewage will sustain.

Plate X shows two groupings of floats set out from station K.

The first shows the position of such of 21 floats, set out between 3.00 A. M. and 2.30 P. M. of June 25th, as could be found within the range of observation at about 3 P. M. of the same day. A contour connects all the positions observed at

approximately the same time, say twelve hours from output of first float.

The second grouping shows in a similar way the position of such of the same 21 floats and of nine others following them in continued sequence as could be found within the range of observation at about noon of the following day—say 33 hours from output of first float. A contour connects all the positions so observed in the latter group, as in the first.

As in the latter grouping, observations near the point of discharge are deficient by reason of the limited corps of observers being fully occupied elsewhere, the contour including simultaneous observations has been closed by taking in the point of output, station K, on the assumption that sewage is pouring out there continuously, and whilst probably diffused in all directions from that point, may certainly be included within the lines closing the contour.

As some particles of sewage may be supposed to reach every exterior point at which a float is observed, it is assumed that during the time occupied in reaching such point some particles will be diffused through the water at every intermediate point, and that consequently the area included within the closed contour will contain at every point some portion of the sewage put out within the time elapsed between the starting of the first float of the series and the time of approximately simultaneous observation.

The inference follows that the sewage discharged in the given time may be considered as dispersed or diffused through a volume of water at least as great as that included within the contour.

The two marginal diagrams on the same plate serve to show graphically the degree of dilution believed to be demonstrated as the result of these observations.

In the diagram A the larger circle represents the superficial area of the body of water 16 feet in depth into which has been dispersed or diffused the twelve hours flow of sewage, the superficial area of which with same depth is represented by the smallest circle, and indicates a ratio of 191 parts of fresh water to 1 part of sewage.

In the diagram B we have similar relations for thirty-three hours flow of sewage extending over an area averaging about 20 feet in depth, indicating a ratio of 333 parts of fresh water to 1 part of sewage.

In both diagrams the intermediate circle represents the superficial area of the body of fresh water, also of same depth, deemed by Messrs. Hering and Gray necessary for adequate dilution, as stated by them in their report (page 146).

The prevailing currents have already proved themselves quite sufficient to keep open the main ship channel to and from Baltimore, and are deemed fully adequate to carrying the relatively small volume of sewage.

The influence of the greater current of the other side of the bay is felt in the channel as Sandy Point is approached, where, at a distance of about 15 miles from the point of outfall, the full effect is had of the whole discharge from the head of the bay, with the full volume of the Susquehanna river.

That a very moderate current, however, will effect all the dilution required may be inferred, when it is noted that by the time the city attains a population of one million the flow of sewage at the outfall will be but 231 cubic feet per second, whilst the ordinary dry weather flow of the Susquehanna alone, as cited by Messrs. Hering and Gray, is 20,000 cubic feet per second, or 35,000 cubic feet per second as cited by General Craighill from gaugings by the U. S. officials, with one or two freshets per year to wash out any possible deposits made beneath a depth of 16 to 20 feet of water.

Such currents can fully dispose of all of the sewage Baltimore may discharge, now or hereafter, and can carry down everything held in suspension.

The report of General Craighill, which will be found as Appendix D to this Report, completely confirms the opinion of your Commission as to the adequacy of the currents of the Bay to effect a satisfactory disposal of the sewage, and leaves open only the question of the particular point at which it may be expedient to discharge it.

CONSIDERATION OF DILUTION PROJECT, A, AS MODIFIED BY RESULTS OF THE STUDY OF THE CURRENTS OF THE BAY OFF NORTH POINT.

The discharge of the sewage at the point K, Plate II, which has been discussed, involves some modification of the esti-

mates for Project A as presented by the Consulting Engineers.

The line of the main outfall sewer, instead of reaching the shore of the Bay just north of Shallow Creek, say about a mile and three-fourths north of North Point, must, by a change of location, be extended across a narrow inlet to the shore of Hart Island, an additional distance of about 6,300 feet, whence the outfall point at Station K is reached by submerged conduits of about 11,000 feet in length.

The latter conduits will be some 1,400 feet shorter than estimated for under Project A. This reduction in length being due to the fact that a depth of 18 feet, thought necessary for the full discharge, is reached at Station K in a shorter distance from the shore than by the line for Project A off North Point.

The additional length of 6,300 feet of main outfall sewer will cost, at the price estimated by the Consulting Engineers, \$189,000. Of this length some 4,000 feet will skirt so near the shore as probably to require protection by rip-rap. For this an allowance of \$10.00 per foot is made, or \$40,000 in all, making the total additional cost of the main outfall sewer \$229,000 to be added to the cost of the first installation as estimated by the Consulting Engineers, thus bringing this cost to \$4,109,167.

The Consulting Engineers provided that the limited amount of sewage at first installation should be discharged at a distance of but one mile from shore. As in the revised location deeper water and improved currents are found in the same distance from shore, no change is made in the length of the submerged conduit for the first installation.

For the completed works Station K, the point selected for ultimate discharge, is reached in a distance 1,400 feet less than to the discharge point estimated for off North Point. The cost of the double submerged conduit is estimated by the Consulting Engineers at \$120.00 per foot, so that the cost of the submerged line is reduced by the sum of \$168,000, leaving the net increased cost of the revised line when completed but \$61,000 more than estimated by the Consulting Engineers, or say \$5,190,167.

This revised line will hereafter be referred to as Project K.

To maintain through the lengthened brick outfall sewer

of Project K the same velocity of flow as provided for in the outfall sewer of Project A will involve a loss of head when the shore of Hart Island is reached of 2.2 feet; whilst to maintain in the shortened submerged conduit the same velocity of flow as provided for in the conduit of Project A requires 0.35 feet less head than in that case; so that we have a net loss of head of 1.85 feet.

To adjust this will require a revision of the profiles when a definitive location is made, and may involve the lifting of the low level sewage through a correspondingly increased height, an adjustment requiring no further consideration here.

COMPARISON OF THE COST OF PROJECTS K AND C.

For the purpose of showing as concisely as possible the relative cost of the two methods of disposal under consideration, the cost of the collection or reticulation system, which is practically the same in either case, and not involved in the question now before us, is separated in the following tables.

COMPARISON OF CAPITAL OUTLAY FOR CONSTRUCTION OF SEWAGE DISPOSAL PLANT BY FILTRATION (PROJECT C) AND DILUTION (PROJECT K).

	(a). First installation. 330,000 population in connection.		(b). Completed Works. 1,000,000 population in connection.	
	K. Dilution.	C. Filtration.	K. Dilution.	C. Filtration.
Estimate of Consulting Engineers for interception and disposal of sewage per Project A.....	\$3,880,167	\$5,741,007	\$5,129,167	\$12,171,803
Add for deficiency in valuation of Glen Burnie lands.....		94,200		
Additional cost of lengthened line of Project K.....	229,000		61,000	
Add for right of way not hitherto estimated.....	25,000	5,000	25,000	25,000
Cost of first installation of Filtration, Project C.....		\$5,840,207		
Cost of first installation of Dilution, Project K.....		4,134,167		
Cost of completed works, Filtration, Project C.....				\$12,196,803
Cost of completed works, Dilution, Project K.....				5,215,167
Saving of cost at first installation in favor of Dilution, Project K.....		\$1,706,040		
Saving of final cost in favor of Dilution, Project K. ...				\$6,981,636
Bringing down the cost of the several stages under each project, and adding the cost of the Reticulation system at each stage.....	\$4,134,167 2,032,500	\$5,840,207 2,032,500	\$5,215,167 5,280,000	\$12,196,803 5,280,000
Total estimated cost of the respective systems at each stage.....	\$6,166,667	\$7,872,707	\$10,495,167	\$17,476,803

**COMPARISON OF ANNUAL COST TO TAXPAYERS FOR INTEREST,
SINKING FUND, MAINTENANCE AND OPERATION OF THE
WORKS UNDER PROJECTS C AND K RESPECTIVELY.**

	(a). First Installation.		(b). Completed Works.	
	Dilution.	Filtration.	Dilution.	Filtration.
Maintenance and operation as per estimate of Engineers' Report.....	\$16,215.55	\$86,760.25	\$29,463.55	\$237,510.00
Add for care of lengthened line and additional pumping, 1 man, and 4% additional on coal and oil for additional pumping	814.80		1,165.20	
Depreciation and renewals as per estimate of Engineers' Report.....	42,276.36	90,319.40	55,826.36	200,029.62
Depreciation and renewals on additional cost, 1% on \$229,000.00 and 1 % on \$61,000 ..	2,290.00		610.00	
Annual interest and sinking fund charge on capital cost of works to extinguish cost in 50 years, money at 3½%,	155,206.68	229,640.28	205,166.68	486,872.12
Add interest and sinking fund charge on right of way, \$25,000.00 and \$5,000	1,000.00	200.00	1,000.00	1,000.00
And on additional cost of out-fall sewer, \$229,000.00.....	9,160.00		9,160.00	
Deduct interest on cost of lands and appurtenances assumed by Engineers' Report as paid by sale of crops....		\$406,919.93		\$925,411.74
		3,968.00		11,368.00
Annual cost to taxpayers on first installation of Project C		\$402,951.93		
Annual cost to taxpayers on first installation of Project K		226,963.39		
Annual saving to taxpayers at first installation by the adoption of Project K in preference to Project C.....		\$175,988.54		
Annual cost to taxpayers on final completion of Project C.....				\$914,043.74
Annual cost to taxpayers on final completion of Project K.....				302,391.79
Annual saving to taxpayers by the adoption of Project K, rather than Project C, at final completion of works..				\$611,651.95
Bringing down the annual cost of the respective projects of each stage, and adding the cost of maintenance of the reticulation system, we have as the total cost of the respective projects at each stage	\$226,963.39	\$402,951.93	\$302,391.79	\$914,043.74
	20,325.00	20,325.00	52,800.00	52,800.00
	\$247,288.39	\$423,276.93	\$355,191.79	\$966,843.74

It will thus be seen that, whilst Dilution Project K will cost at completion \$5,215,167, the other, or Filtration Project C, will cost \$12,196,803 or two and one-third times as much.

And further, that the annual cost of operating Dilution Project K, including interest and sinking fund, will be \$302,391, whilst that of Filtration Project C is \$914,043, or three times as much.

The annual saving of \$611,652 effected by adopting the Dilution Project K will amount in nine years after completion to more than the entire cost of the dilution plant; whilst at the end of twenty years such saving, could it be realized, would aggregate more than the entire cost of Filtration Project C, as estimated by the Consulting Engineers.

EFFECT OF A DISCHARGE OF THE SEWAGE INTO THE WATERS OF THE BAY UNDER PROJECT K.

It has already been shown that there are no shores on which the sewage is likely to impinge and but little possibility of its being noticeable at any considerable distance from the point of outfall. It must be remembered that *sewage* is not *garbage*. The latter consisting of tin cans, pea hulls, corn cobs, etc., would probably, if discharged into the bay, float upon the surface and create a nuisance for a considerable distance, no doubt drifting to the shores. No such material forms any part of the sewage which would be conveyed in the conduits of your system. Besides, the whole of the sewage would receive from two to three screenings through openings not exceeding one or one and a half inches in width, so that the matter carried in suspension will be very much comminuted before reaching the outfall, where its appearance will not differ greatly from that of dirty wash water.

We have, too, already noted as the result of enquiry that, not only are no merchantable oysters now taken at or near the point of projected outfall, but that none such have been taken in that locality in recent years.

It has also been ascertained that such oysters as do grow there are of inferior size, mostly "culls," and cannot be made use of unless, by transplanting, they may serve as seed or plants elsewhere. At present no such use is made of them.

Should their use for such purpose become desirable hereafter, we have seen by the observations and conclusions of Prof. Herdman, already referred to, that the deposit of the oysters in water free from pollution gradually removes all trace of bacteria. So far as your Commission has been able to learn, no observer has found trace of the typhoid bacillus in the oyster 21 days after exposure.

If these statements made to your Commission or developed by their investigation of recorded observations elsewhere be facts, as your Commission believes them to be, it would appear that no offense can be caused and no existing commercial interest can be affected injuriously by a discharge of the sewage at the point indicated under Project K. And should it be found expedient to obtain legislation, granting to the City of Baltimore the exclusive right to take oysters within a certain defined range surrounding the sewage outfall, the city will have under its own control all questions in regard to the effect of such discharge on neighboring oysters, should the future develop the existence of any such beds.

COMPARISON OF PROJECTS K AND C FOR BALTIMORE WITH THE SYSTEMS OF SOME OTHER CITIES.

In order that opportunity may be afforded for observing the relative conditions which obtain in several cities whose new and improved sewerage systems it may be desired to compare with those suggested for Baltimore, Plate V has been prepared.

This shows graphically for the cities of Paris, Berlin, Melbourne and Boston, as well as for our own city, the population, volume of sewage output per day, pumpage per day, and lastly, the landed area in use or required by those of the cities named by which the filtration or irrigation processes are used or proposed.

By diagram 2 of Plate V it will be seen that Baltimore, with its forecast population of one million, has to provide for a daily volume of sewage, without storm water, 43 per cent. greater than that of Melbourne, also with no storm water and the same population; 27 per cent. greater than that of Paris with a limited amount of storm water and a popula-

tion of $2\frac{1}{2}$ millions; 233 per cent. greater than that of Berlin, with limited storm water and a population of 2 millions; and 34 per cent. greater than that of Boston, with limited storm water, whilst exceeding the forecast population of the latter city by but 25 per cent.

Diagram 3 of the same plate shows the amount of daily pumpage required in disposing of the sewage of the several cities, and includes for Baltimore both Projects K and C. Here it will be observed that the Baltimore Filtration Project C will involve an amount of pumping only about 11 per cent. less than that of Paris, when the latter is developed for its $2\frac{1}{2}$ millions of population.

The same diagram illustrates one of the principal sources of economy in the proposed Dilution Project K; the only pumping required being less than 9 per cent. of that shown for Project C.

It serves also to show the economy in this respect of Project K for Baltimore compared with the same feature of the Boston system. The pumpage for Baltimore with forecast population of one million being only 25 per cent. of that of Boston, with forecast of 800,000 population.

Diagram 4 of Plate V shows the relative amount of filtration area or farm lands required or estimated for the several cities using or proposing filtration methods.

Here we see illustrated the estimated efficiency of the Anne Arundel soil for filtration purposes, which will enable 5,400 acres there to dispose of 150 million gallons of sewage per day, whilst at Melbourne 8,900 acres are thought necessary for 105 million gallons. The acquisition of 22,200 acres shown for Berlin is probably largely in advance of its immediate needs, more especially as the population of that city uses but 28 gallons of water per head per day, where the citizens of Baltimore now use or waste from 87 gallons to 100 gallons daily. It would seem either that the filtering power of the soil of the Berlin farms is much inferior to that expected of the Anne Arundel sands, or the land has been secured from economic reasons long in advance of necessity therefor.

Comparison with Paris indicates a much larger acreage per million of gallons daily delivered than has been thought necessary for filtration of the Baltimore sewage. Perhaps the excess of land provided for both Paris and Berlin is due

to the larger acreage devoted to broad irrigation in the schemes for those cities, whilst in Anne Arundel county irrigation of the farm lands would be incidental and has not been deemed the main object.

In Plate VI is presented graphically the relative cost of Projects C and K compared with that of works in the other cities already cited.

Fig. 1 shows the capital cost. The horizontal black line divides the cost of the disposal system, shown above the line, from the collection, or as we have termed it, the reticulation system, below the line.

Fig. 2 shows in the same manner the annual cost of maintenance and operation.

The columns colored in full show the cost for the several cities at last advices, and for Baltimore when progressed to the point of serving 330,000 population. Extensions of the columns in outline indicate the further cost of maintaining the projected works, and in the case of Baltimore when the works are serving one million of people, and indefinitely thereafter. To the Baltimore columns have been added hatched sections representing the annual charges for interest and sinking fund on cost of the works, which will continue for say 50 years or until the debt incurred for the works has been paid off by the operation of the sinking fund. These items have not been obtainable for the other cities, except Berlin, for which the amount is given as upwards of one million dollars annually.

CONCLUSIONS.

The Sewerage Commission having carefully considered the whole subject, having duly weighed the recommendations of its expert advisers and at the same time kept in mind its duty to the taxpayers of the City of Baltimore, now presents to the Mayor and City Council and, through them, to its fellow-citizens, its conclusions and recommendations.

It deems it of paramount necessity that storm water and domestic sewage should be collected separately and separately disposed of.

That subsoil drainage should also, as far as possible, be separated and disposed of with the storm water.

That the storm water should pass by way of the existing storm-water drains and natural watercourses to the river and

harbor as now. From these and their future extensions should be excluded, as soon as the development of the system now recommended makes this possible, all domestic sewage and foul matter except street washings.

That the domestic sewage should be collected by a system of high level and low level intercepting sewers on lines substantially as laid down on the plans and profiles shown on Plates III and A, and disposed of by a continuous discharge into Chesapeake Bay at a point approximately located at K on the chart, Plate II, being some two and a half miles about due east of the Rear Range Light of the Craighill Channel. The high level intercepting sewer, serving about three-fourths of the forecast population of the city, will reach this point by gravity. The low level intercepting sewer will collect at a point on the left or east bank of Jones' Falls opposite Water street all the drainage from the outlying low grounds of Fell's Point, Oldtown, Locust Point, Ferry Point, and such portions of the more central portion of the city as lie below the level of the gravity flow, and from a single pumping station there located will lift and force the low level sewage, about one-fourth of the whole, into the gravity sewer at a point near the intersection of Broadway and Lombard streets, whence all will flow together by gravity to the outfall in the bay.

The reasons which have controlled the Commission in arriving at the conclusion that this method of disposal is the best for the City of Baltimore have been already discussed in detail. They may, however, be briefly summarized here.

There are three possible methods of disposal.

First. By dilution into the waters of the bay.

Second. By chemical precipitation of the solids and disposal of the effluent into the river or bay.

Third. By filtration upon lands in Anne Arundel county.

The second is eliminated as offering no advantages when either the first or third can be made to serve efficiently the desired end, unless indeed as a temporary expedient in connection with the ultimate adoption of the third.

The third method, being the one recommended by Messrs. Gray and Hering, is both theoretically and practically the best method of disposal. It returns to the earth the organic matter originally derived from it and leaves the watery portion of the sewage remaining after irrigation of the soil and crops to pass off in a state bordering closely on purity.

Better soil for use with this method than that of Anne Arundel county is rarely found, and there could be no hesitation in accepting it as the method best adapted to our needs were it not that its first cost at completion is not only more than double that of the first method, but the annual cost of working it is about three times as much as the other.

This consideration of excessive cost has had much weight with the Commission, and whilst it could not have led it to recommend an inefficient project under any circumstances, it has induced a particularly careful examination of all the arguments likely to be presented against the method now recommended.

These enquiries and investigations have satisfied your Commission that the adoption of the system by which the sewage will be discharged into the bay will cause no injury, present or prospective, either to the people who dwell along the shores of the bay or to the important commercial interests in which Baltimore itself has so large a stake, and the Commission realizing its responsibility deems itself fully warranted in the conclusions at which it has arrived.

Messrs. Gray and Hering, our Consulting Engineers, each recognize and state that the waters of the bay are quite adequate for the purpose of effective dilution, although they recommend a different disposal as the best; whilst General Craighill, who has also been consulted, with his special knowledge of the tides and currents of the bay, has expressed his conviction of their adequacy to effect the entire removal of the sewage without offense to any.

There would certainly appear to be but little reason why the City of Baltimore should deny itself the facilities and advantages which nature has vouchsafed to it and at great expense seek another method of disposal lest pollution should be added to the waters of the bay, when, do what it may, the cities and towns along the shores of the bay and the great rivers which empty into it will continue to make use of it as they do now, emptying their sewage and other wastes at will. Ships will come and ships will go. They will drop all sorts of matter directly over and upon the oyster beds. It would be ridiculous to attempt to prevent it. May not Baltimore as well, without offense to others, modestly purify herself in the broad waters of this great bay without thereby disturbing or annoying any existing interest? Your Commission thinks she may.

The complete system of sewerage here recommended with disposal by dilution in the waters of Chesapeake Bay at the point indicated may be effected by the expenditure of a sum, which it is estimated will reach the amount of \$6,166,667, by the time the outfall works are completed and the reticulation system of laterals sufficiently extended to serve, say, 330,000 persons, a sum which will be increased from year to year as the laterals of the reticulation system are extended and more of the population brought into connection with it, until, when the whole city area is connected with the system, say by the year 1925, the cost will reach the estimated total of \$10,495,167; these sums being respectively \$1,706,040 and \$6,981,636 less than the cost at similar stages of progress of the filtration method of disposal upon the lands of Anne Arundel county.

Whilst this economy of first cost is found in the disposal of the sewage into the Chesapeake, the saving of annual expense for interest, sinking fund and maintenance is no less marked in favor of such disposal. From the time the works are completed until the debt incurred for construction is paid off, the Chesapeake disposal will cost per annum but about one-third of the annual cost of the filtration method, and when the debt is paid the annual cost of the Chesapeake disposal becomes less than one-third of the other.

METHOD OF MEETING THE COST OF THE SYSTEM RECOMMENDED.

In view of the fact that taxation has in the past borne heavily on the citizens of Baltimore, it is deemed well to discuss here the additional burthen which will be caused by undertaking the sewerage works now under consideration.

If the recommendations of the Commission be adopted by the city, an expenditure estimated at \$6,166,667 must be made before the new system can be opened to use in a partially completed state, and with a portion of the population connected therewith, or say 330,000. So much of the work might perhaps be accomplished in three years from date of closing the contracts for construction; but it is much more likely that five years will be consumed in effecting it. If so, the average yearly expenditure will be \$1,233,000. As the work will of course be paid for by the proceeds of a loan to

be authorized and effected for the purpose, there must be raised by taxation the sum of \$49,300 to meet the interest and sinking fund payments for the first year's outlay. This will increase from year to year as the work progresses until at the end of five years the works are opened for use.

Of the amount thus far expended, \$2,032,500 will have been spent in constructing the district mains and laterals of the reticulation system. The cost of these it is usual in other cities to assess directly against the real estate benefited, on the same principle, or rather for the same reason, that governs the assessment of cost for opening streets.

Should the same method obtain here, the city treasury will be recouped by the end of the five years, or shortly thereafter, in the sum of \$2,032,500, advanced for this portion of the construction from the funds of the loan, and the sum so recovered will be, according to estimate, sufficient to carry forward to completion the main works; whilst the extension of the reticulation system will be paid for by assessment for benefits as before.

From the time the works are first opened to service, the current annual charges may be most readily met by an annual sewer rate, charged against the property enjoying the benefit of sewer connection, on a basis similar to that which obtains in the City's Water Department.

Reference to the table on page 74 shows that the total annual charges at first installation will be \$247,288.39.

The last report of the Water Department shows a total of 92,779 houses and warehouses yielding revenue for the use of water at rates per house varying from \$3.00 up to \$16.00.

Assuming that the number of houses supplied with water includes a small proportion outside the city limits, the population served is probably not less than 520,000. If so, the population of 330,000 connected with the sewers at the out-start may, at the same ratio, be attributed to 58,879 houses.

Now a sewer tax averaging \$4.20 per annum for each one of these 58,879 houses will yield \$247,291, a trifle more than is required to meet the annual charges for running and keeping up the works, paying the interest on their cost and, by proper payment to the sinking fund, extinguishing in fifty years the debt incurred for their original cost.

Although an average charge of but \$4.20 per house is so small that it will be a burthen to none, it may be well to

show the large offset there still remains in the saving to property owners of the cost now incurred for cleaning cesspools.

The reports of the Health Department for the last three years show an average of 92,568 loads of filth removed from cesspools cleaned each year. An enquiry made by your Commission into the methods of doing this work has satisfied it that the reports do not show all the stuff removed. It has been stated that little or none from the 21st and 22d wards reaches the dumps, whence the tally is reported to the Health Department, and that an addition of 10 per cent. to the amount reported to and by the Department would not more than cover the quantity diverted in violation of law from the proper dumping places.

Nevertheless, neglecting any correction of the total number of loads of stuff reported as removed, we find the 92,568 loads reported as taken away each year is just about one load for each house of about 92,779 houses and warehouses in the city. Now the charge made for privy cleaning is \$2.50 for each load removed, so that whilst some pay more and others less, and some escape altogether, yet on an average each house owner pays \$2.50 each year for this process.

This of course will be saved when sewer connection is effected, so that the average annual cost to the average house owner will be but \$1.70 more for the efficient service of the new system, than is now paid annually under our existing method.

This showing is based upon present conditions and upon the assumed population of 330,000 that will be connected with the sewers when they are first opened for use.

As the works are extended the house connections will increase, so that when the population reaches one million connected with the sewers, taking the same ratio of houses to population as at present, there will probably be as many as 178,000 houses from which to collect the revenue for the maintenance of the works, interest and sinking fund, the total of which is estimated for that period at \$355,191.79 (see table, page 74).

This will be more than met by an average house rate of \$2.00.

When, after the lapse of 50 years, the cost of the works has been paid off through the operation of the sinking fund,

an average house rate of one dollar will more than suffice to meet the estimated cost of maintenance.

The construction of this system of improved sewerage will leave the existing sewers or drains no other functions to perform than the carrying off of storm water and street washings.

The latter, unless intercepted by proper catch-basins, will still reach these drains as now and will be carried along with the storm water through them to the Basin, to Jones' Falls, or directly to the river, from which they will be removed by periodic dredging as at present. All domestic sewage, however, including water-closet drainage, will be cut off and intercepted by the new system. The flooding of sidewalks and street crossings with bath and laundry water in the winter season when the gutters are obstructed by ice will no longer be characteristic of our city.

It may be safely anticipated that, with the removal of the large quantity of organic matter which is now discharged into them, the offensiveness of the Basin and the Harbor generally, now so serious a cause of complaint, will entirely disappear.

The emptying and cleansing of all existing cesspits, promptly followed by the filling of the empty pits with clean material, will surely produce in our city, as it has invariably done elsewhere, an improvement in the general health of the city and a marked reduction in the death rate.

The subsoil drainage of the low grounds of the city, which it is contemplated will be an important feature of the system now recommended, should improve the health of the localities so drained, and should, according to all experience, have notable effect in lowering the death rate from consumption; at the same time it will render available in them for storage and business purposes basements and cellars which at present are quite useless.

Thus will be enhanced the value of property in sections of the city which have suffered by reason of the difficulty of introducing improvements now generally regarded as essential.

RECOMMENDATIONS.

Should this Report and its conclusions be accepted by the Honorable the Mayor and City Council, it is respectfully

recommended, that this, or another Commission be authorized with the aid of the City Solicitor, to prepare an enabling act to be submitted to the General Assembly of Maryland, at its approaching session; so that by the adoption of such act the city may be enabled to commence the work of construction with as little delay as possible.

Also, that without waiting for the final ratification of such enabling act a competent civil engineer be appointed as Chief Engineer, who, with the aid of necessary assistants, shall at once proceed to make a definitive location of the works here recommended with revised estimates, so that there need be no delay in letting the work, should it be authorized by the Legislature and the people.

Such careful revision will only result in effecting economies that cannot at this stage be anticipated.

It is further recommended that no additional storm-water drains or so-called sewers, nor extensions of any already existing, be authorized without the approval of such Chief Engineer, in order that wasteful and unnecessary expenditure of public money may in the future be avoided.

Inasmuch as the location of the main gravity intercepting sewer with a continuous flow of sewage from the extreme western section of the city to the outfall in the bay will naturally admit of but very slight deviation from the natural gradient adopted and but slight, if any, change from the streets which such gradient will determine, it is recommended that no future subway work be undertaken by other departments without consultation with such Chief Engineer, in order that unnecessary interference and increased expense may be avoided.

The Commission would here remind the Mayor and City Council that at least twice before has the City of Baltimore undertaken to investigate the sewerage problem.

Under Mayor Thomas Swann a joint resolution, approved September 26th, 1859, appointed a Commission to investigate the subject. This Commission reported in 1862, but no action seems to have been taken thereon.

Under Mayor Ferdinand C. Latrobe a joint resolution, approved February 8th, 1881, authorized the appointment of a civil engineer to examine and report upon the question of establishing a general system of sewerage in the city.

Under this resolution Mr. C. H. Latrobe was appointed. His report was made to the same council; but, although a joint committee, to which it was referred, seems to have recommended the carrying out of his plans, we have no evidence that any steps in this direction were ever taken.

Now the problem has again been submitted to the members of the present Commission, who have had the responsibility of disbursing a large amount of money in the work and who have contributed assiduously their own time and labor to its investigation and determination.

The Commissioners venture to hope that some definite action will be had upon this Report, and if its recommendations meet with approval, that steps will be at once taken towards the construction of the works.

The Commission desires also to express its thanks and record its obligation to those who have in various ways aided it with the results of their experience and observation.

It would particularly mention its indebtedness for maps, charts, statistics and special information to Brig. General Wm. P. Craighill, U. S. A., retired, late Chief of Engineers, for so many years in charge of the harbor improvements of Baltimore, and the approaches thereto; to Col. P. C. Hains, Corps of Engineers, U. S. A., now in charge of the same works; to Prof. T. C. Mendenhall, late Superintendent of the U. S. Coast and Geodetic Survey, and to Gen. W. W. Duffield, his successor in that office; to Lieut. E. H. Tillman, U. S. N.; to Lieut. Edward Simpson, U. S. N., Hydrographic Officer at Baltimore, and to Mr. A. P. Davis, Hydrographer, U. S. Geological Survey; to Mr. F. P. Stearns, former Engineer of the State Board of Health of Massachusetts and to Mr. X. H. Good-nough, his successor in that office; to the chiefs of the several departments of the City administration, and especially to Dr. James F. McShane, Commissioner of Health, to Major N. H. Hutton, Engineer of the Harbor Board, and to Mr. C. H. Latrobe, Engineer and Superintendent of Parks; to Messrs. Wm. T. Manning, Chief Engineer of the Baltimore and Ohio Railroad, George C. Wilkins, General Agent of Pennsylvania Railroad, J. M. Hood, President of Western Maryland Railroad Company, Wm. R. Hutton and to Prof. P. R. Uhler.

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In final conclusion your Commission desires to acknowledge the faithful and efficient service of its several assistants:

Mr. Calvin Whiteley, Jr., who has had charge of parties in the field.

Mr. P. C. Kennedy, who has had similar charge, and who also conducted the float observations in Chesapeake Bay.

It desires especially to express its sense of the industry and skill which has been brought to its service by Mr. Kenneth Allen, its Principal Assistant Engineer, who has, under its direction, conducted all the surveys and observations found necessary in the prosecution of the work, besides aiding the Commissioners with his accumulated knowledge and experience.

The Commission would also bear testimony to the faithful work of Mr. C. L. Rector, Clerk to the Commission, who has kept its accounts and has had charge of its correspondence and records.

All of which is respectfully submitted.

MENDES COHEN,	}	<i>Sewerage Commission of the City of Baltimore</i>
F. H. HAMBLETON,		
E. L. BARTLETT.		

BALTIMORE, 20TH SEPTEMBER, 1897.

APPENDIX A

DESCRIPTION OF INTERCEPTORS

PROJECT K

DESCRIPTION OF INTERCEPTORS—PROJECT K.

The approximate location of the intercepting sewers in Project K may be seen by reference to Plate A, furnished by the Consulting Engineers for Project A, and their profiles are shown on Plate III, appended to this Report.

The main or high-level interceptor, which is extended to the eastward of the city as the outfall sewer, collects the sewage from that portion of the city lying above or to the north of it and conveys it to the outlet in Chesapeake Bay by gravity.

The entire sewage of the valley of Gwynn's Falls and Gwynn's Run lying to the north will be collected at the intersection of Wilkens avenue and Bentalou street, from which point the interceptor 4 feet 10 inches in diameter is projected southeasterly to the Baltimore and Ohio R. R. right of way, thence parallel to the same to Calhoun street, in Calhoun to Hollins street, Hollins to Carey, to Lombard and under the Calhoun Street and Carey Street Drains. It is here 5 feet 8 inches in diameter and will require a modification of section to pass under the drain. It continues in Lombard to Schroeder, Pratt, Scott and Lombard streets, and up Fremont avenue to German street. Here it passes in a siphon of two 34 inch cast iron pipes under the Pine Street and Arch Street Drains near their junction at Penn street, over the Baltimore and Ohio R. R. tunnel, which is just cleared at German and Howard streets, up the latter to Fayette street, and eastward in that street. At Park avenue, where it is 6 feet 6 inches in diameter, the Liberty Street Drain, 4 feet 6 inches in diameter, will have to be carried under the sewer. Continuing in Fayette street to St. Paul street, it turns northerly into the latter, whence it continues to Madison street, to Calvert street, to Eager street, to Guilford avenue, thence northerly a short distance, thence easterly, 7 feet 10 inches in diameter, and dropping by a shaft to a lower level it extends as a siphon of two 42 inch steel pipes under Jones' Falls approximately 200 feet north of Eager street. On the eastern side of the Falls it rises again and runs south to Eager street, thence to Forrest street, to Madison street and to Caroline street. At Eden street, where it

is 10 feet 2 inches in diameter, the Central Avenue Drain, about $6\frac{1}{2}$ feet in diameter, interferes and will require re-location. The line continues southerly on Caroline street to Mullikin street, to Bond street, to Fairmount Avenue, to Bethel street, to Baltimore street, to Broadway and to Lombard street.

Here it receives the discharge of sewage collected by the low-level system and pumped to this point through iron mains and is enlarged to a diameter of 11 feet 4 inches. It then continues easterly to Ann street, to Pratt street, to Chapel street, to Gough street, to Duncan alley, to Bank street, to Patterson Park avenue, to Eastern avenue and easterly on Eastern avenue, diverging into an embankment in the south side of Patterson Park, to Streeper street. Here it turns to the south, and in order to cross Eastern avenue the grade of that avenue will have to be slightly raised.

At Fait avenue it runs eastward to Patuxent street, then to Hudson, to Potomac, to Dillon, to Clinton, to O'Donnell, to Highland avenue and to Elliott street.

From this point the line continues in a general southeasterly direction to the outfall in Chesapeake Bay, crossing Bear Creek by a siphon on the way.

This outfall sewer which, from near Harris Creek, is 12 feet 4 inches in diameter, is designed to take the maximum discharge from the forecast population of one million when running two-thirds full; and its gradient will ensure a uniform velocity of about $4\frac{1}{4}$ feet per second. These conditions, with the elevation at outlet for a free discharge of the sewage, are elements which control the area of the city which may be served by the high-level interceptor without pumping.

The lower portions of the city—those lying to the south of the above line, drain to interceptors which collect the sewage to a pumping station on the east side of Jones' Falls, a short distance north of Lombard street, from which it is pumped through force mains to the high-level interceptor at Lombard street and Broadway.

The West Low-level Interceptor runs northeasterly from Putnam street on Russell, where it may, if required, collect the sewage from a considerable territory lying beyond the present city limits. Russell street for three or four blocks is as yet but a marsh, and will have to be raised several feet. At Bush street, where the interceptor is 3 feet 3 inches in diameter, it passes in two 16 inch iron pipes under the Bush Street Drain. It also passes under the Allu-

vion Street Drain to Stockholm street, to Leadenhall, to Montgomery, to Charles, to Balderston, to Light, to Lombard, to Calvert, to Water street, where its diameter is 6 feet 6 inches, and under Jones' Falls in two 34 inch steel pipes to the pumping station. It is so designed as to provide a velocity of 4 feet per second when running half full.

Two interceptors from Locust Point will enter the West Low-level Interceptor, one at Stockholm and Leadenhall streets, and one at York street. The former will collect the sewage from the greater part of Locust Point, and is located on Clement, Allen, Winder, Race, Barney and Leadenhall streets to Stockholm. In size it varies from 20 inches to 4 feet 10 inches in diameter. The York street interceptor drains a narrow district to the northeast of a line between Federal Hill and Riverside Park, and is located on Belt, Rupert, Montgomery and Covington streets, Hughes and Battery avenues, and York street to Charles street. It is of 15 inch and 20 inch pipe. The velocity in these two interceptors will be three feet per second when half full.

The East Low-level Interceptor runs along Glover alley from Canton street to Foster avenue, with a diameter of 18 inches, to Luzerne street, to Hudson street, to Boston street, to Aliceanna street, to Caroline street, to Eastern avenue, to Albemarle street, to Lombard street, and along Front street to the pumping station, where it is 36 inches in diameter. Below Aliceanna and Caroline streets, the velocity when half full is four feet per second, but above this point it is somewhat less in order to keep under cover.

APPENDIX B

STORM-WATER DRAINAGE

STORM-WATER DRAINAGE.

A.—EXISTING DRAINS.

In order to arrive at a fair conception of the adequacy of the existing drains to discharge the flow-off of their respective watersheds, it has been necessary to make certain assumptions as to the intensity of rainfall, the character of the inner surface of the drains, etc., based upon which their requisite and actual capacities have been calculated, with brief comments as to the results. It is not to be supposed that these are in all cases conclusive, as certain factors affecting the problems were often unavailable. For example, what extensions or interceptors were contemplated in the design? What are the limits of the intended drainage area affected as it may be to a considerable extent by the arrangement of inlets, the altering and establishing of street grades? What is the character of the inside surface as to smoothness and resistance to erosion? Manifestly, without knowledge on such points, no refinement in calculation will give exact results. But it is believed that the conclusions which have been drawn will indicate in a general way the extent to which the several drains are fitted to perform their appointed work.

It has been assumed as reasonable:

First. That a rate of not less than $3\frac{1}{2}$ inches of rainfall per hour should be provided for, 80 per cent. of which will eventually flow directly to the drain.*

While the elements that control the run-off from an area of ground are too numerous to enable us to predict the resulting storm discharge by means of a formula with precision, yet for general purposes the McMath form of the Burkli-Ziegler formula is well adapted to the conditions prevailing in Baltimore and has been used here in estimating the storm water to be cared for.

*It is understood that many of the drains are designed to provide for a maximum of two inches of rain per hour. The percentage of flow-off to the drain varies from about 30 for rural districts to nearly 100 in compactly built districts with impervious pavements, but for the present purposes 80 has been assumed as generally applicable to the built-up areas in Baltimore.

This formula may be expressed as follows:

$$Q = cr\sqrt{A^4S},$$

in which

Q = run-off in cubic feet per second.

c = a coefficient corresponding to the proportion of the rainfall that will flow directly to the drain.

r = the maximum rate of rainfall in inches per hour which will be provided for.

A = the drainage area in acres.

S = The average fall per thousand in surface of drainage area.

Second. That in calculations for the capacity of drains the interior surface may be taken as equivalent to that of good brick-work, and that in older stone drains allowance may be made for their probable condition. These latter, however, are almost always of ample size.

It is scarcely necessary to explain that a channel with a smooth interior will discharge a greater volume of water than one with a rough or irregular surface, causing more friction and the formation of eddies which retard its easy flow.

To provide for such differences the formula used contains a factor varying with the degree of roughness, which was determined by the collation of the results of numerous experiments.

It is therefore apparent that the estimated capacity of a certain drain depends materially on the coefficient which has been assumed in the calculations, a low coefficient of roughness presupposing a smooth surface, giving a greater discharge than a high coefficient.

In the calculations for capacity Kutter's formula was employed with a coefficient of roughness = 0.013, the newer drains, at least, being well finished inside.*

$$v = \frac{41.65 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \frac{n}{\sqrt{r}} \left\{ 41.65 + \frac{0.00281}{s} \right\}} \times \sqrt{rs},$$

* *Note:* In a few cases where the cross sections are not circular, the capacities are calculated by Bazin's formula (as adapted to brick-work and cut stone), $v = \sqrt{1 \div .0000133 \left(4.354 + \frac{1}{r} \right)} \sqrt{rs}$. As this is a suitable formula for the purpose, it has not been thought necessary to re-calculate such sections by the Kutter formula.

v = mean velocity of discharge in feet per second.

n = a coefficient depending on the character of the inside surface of the drain.

r = the mean hydraulic radius of the drain in feet.

s = the fall in the hydraulic grade per unit of length.

Third. That their construction and stability were such that they might flow nearly full without danger of rupture and that exceptional velocities up to about 18 feet per second would not be prohibitory.

To what extent these assumptions are admissible is not known. If allowed to flow but two-thirds full the list of inadequate drains would of course be increased.

Generally, where of insufficient size, a lateral entering the main below or an intercepting drain with an independent outfall may be constructed which will afford requisite relief of the gorged section. It is quite possible that, in some cases, the necessity of such relief has already been anticipated.

1.—DESCRIPTION OF DRAINS.

I. *The Harris Creek or Harford Run Intercepting Drain* empties into the Northwest Branch' of the Patapsco River near the intersection of Boston and O'Donnell streets, and, following the valley of Harris Creek through Patapsco, Monument, Chester, Eager and Wolfe streets, terminates north of North avenue east of Chester street. It drains the entire valley of Harris Creek and, in general, that portion of Harford Run valley lying north of the Union R. R., in all nearly 2,000 acres. This is the greatest area tributary to any one drain in the city, and the drain itself is the largest in size, being for 2,267 feet (to Eastern avenue) 24 feet wide and 9 feet high inside, while in section it is a segmental arch spanning a rectangular channel.

Its principal laterals are as follows:

1. The Ogier Run Lateral branches from the main drain in Patterson Park and extends in a northeasterly direction to a point outside the park boundary. This drains about 680 acres and has a diameter of 7 feet.

2. The Patapsco Street Drain extends from Monument street north to the Union R. R. and has a diameter of 6 feet.

3. The Ann Street Lateral extends from Eager to Hoffman street, and terminates north of Gay street and the Union R. R.

4. The Federal Street Lateral extends in that street from Wolfe street to Caroline street.

II. *The Broadway Drain* runs from the foot of Broadway through that street to Gough, Ann, Baltimore and Wolfe streets to Jefferson street, draining an area of about 120 acres. Below Canton avenue it is generally a horizontal ellipse 7 feet by 4 feet in dimension, and above that point circular, with diameters of from 4 to 3 feet.

III. *The Eden Street Drain* extends from the foot of Eden street at the City Dock to Eastern avenue, and thence a short distance west.

The lower part is a 6 foot by 3 foot 3 inch ellipse with a grade of 0.224 per cent., while the upper portion is of uncertain section.

IV. *The Central Avenue Drain* extends from the City Dock along Central avenue, Holland and Eden streets to Monument street, and thence northeasterly to Ann and Eager streets, draining the valley of Harford Run below the Harford Run Intercepting Drain, about 410 acres in all.

Below Canton avenue this is an open channel 22 feet wide, and between Eastern avenue and Lombard street a segmental arch about 20 feet in span with a rectangular invert, the height being 4 feet 6 inches in the clear inside. Similar sections, but of reduced size, are used for the balance of this drain, excepting sections from Holland street up Eden street to near Monument street, which is a 10 foot by 6 foot ellipse; from this point to Bond and Abbott streets, which is a circle 6 feet 6 inches in diameter, and from Barnes street to Ann and Eager streets, which is a circle 7 feet 6 inches in diameter.

Laterals to this drain are:

1. The Eden Street Lateral branching from the main drain at Eastern avenue, and extending to Eden and Lombard streets. This is 4 feet 2 inches in diameter to Pratt street, and then 2 feet 6 inches in diameter.

2. The Central Avenue Lateral, which extends in that avenue from Holland street to Madison street, with diameters of from 5 feet to 3 feet.

3. The Orleans Street Lateral, which consists of a 24-inch cast iron pipe extending in Orleans street to Bond.

V. *The Necessity Alley Drain* empties into Jones' Falls on the east and runs through Fayette and High streets and Necessity alley to Chesnut street. It varies in diameter from 3 feet 6 inches to 2 feet 9 inches.

VI. *The Low Street Drain* discharges into the east side of Jones' Falls at Low street, and runs thence in Low street, Rogers avenue and Front street with diameters of 5 feet and 4 feet 6 inches.

There are two laterals, viz.:

1. In Low street east of Rogers avenue, and
2. In Ensor and Mott streets.

VII. *The East Monument and McKim Street Drain* discharges into Jones' Falls at Monument street and runs through Monument and McKim streets to Eager street. It is a 3 foot by 4 foot box with grades of from 1.07 to 1.77 per cent.

VIII. *The Eager Street Drain* runs from Jones' Falls at the foot of Eager street to Valley, to Chase, to Ensor, and to Biddle streets. It varies in diameter from 5 feet to 3 feet.

IX. *The Jenkins Run Drain* empties into Jones' Falls between Preston and Hoffman streets, runs northerly via Carter alley to a point 135 feet north of Lafayette avenue, and thence northeasterly to a point in Boone street north of Twentieth street. For 3,270 feet, to a point in Walcott street, it has cross sections of from 163 to 49 square feet, and is built with a segmental arch. Above this it is circular and 10 feet 6 inches in diameter. It drains nearly 900 acres, including Homestead and that part of Waverly east of the York Road.

It has two principal branches:

1. In Hoffman street to Homewood avenue, 4 feet in diameter;
2. In Girard avenue to Barclay street, 3 feet in diameter.

X. *The Lovegrove Alley Drain* empties into Jones' Falls between Charles and St. Paul streets, and runs through Lovegrove alley to Twenty-first street, and then in a general northeasterly direction to Guilford and Huntingdon avenues.

From its mouth to Adams street it is a 2 foot by 6 foot box spanned by a 6 foot semi-circular arch. From this point a 6 foot by 6 foot 6 inch ellipse is carried to Twenty-first street, above which its section and grade are unknown. North of Twenty-third street it has been built and maintained as a private drain.

XI. *The North Charles Street Drain* extends from Jones' Falls, east of Maryland avenue, to Lanvale and Charles streets, and thence northerly to a point about 60 feet beyond Twenty-second street, with diameters of from 5 feet 6 inches to 3 feet 9 inches.

XII. *The North Avenue and Druid Hill Avenue Intercepting Drain* was built to divert a portion of the drainage of the old McMechen Street Drain (XIII). From its outlet to Jones' Falls at North avenue to North and Park avenues, it is 8 feet in diameter and the grade—generally 1.5 per cent.—is broken by several drop-wells. From North and Park avenues to Laurens street and Druid Hill avenue it is 7 feet in diameter. At this point it reduces to a diameter of 4 feet 6 inches.

It takes the drainage of some 265 acres.

The Druid Hill Avenue Drain was intercepted by the drain just described at Laurens street, above which point it is now an extension of it. Its diameter is 4 feet 6 inches as far as Bloom street, from which point it continues to above North avenue with a diameter of 4 feet.

The Division Street Lateral enters the main drain at Bloom street and runs thence on Bloom, Division and Gold streets to and a short distance up Pennsylvania avenue, varying from 3 feet 6 inches to 3 feet in diameter.

XIII. *The Mosher, John and McMechen Streets Drain* discharges into Jones' Falls between Mosher street and Lafayette avenue, and runs thence through Mosher, John and McMechen streets, Morris alley, Wilson street and Druid Hill avenue to Laurens street, where it is cut off by the North Avenue and Druid Hill Avenue Intercepting Drain. It varies in size from an arched culvert 12 feet wide and 15 feet high to a circle 4 feet 6 inches in diameter.

The Rutter Run Lateral extends from the Northern Central R. R. northwesterly to a point north of North avenue and west of Mt. Royal avenue. It is an old arch culvert varying from 12 feet to 5 feet in width and from 9 feet 6 inches to 5 feet in height.

It has a lateral running from a point 80 feet south of McMechen street into and along that street to Rutter street, varying from 4 feet 6 inches by 4 feet 6 inches to 3 feet 6 inches by 3 feet 6 inches in section and now serves for a small area lying between the North Avenue and Druid Hill Avenue Intercepting Drain and the McMechen Street Drain.

XIV. *The Preston Street Drain* discharges into Jones' Falls under the Maryland avenue bridge, and runs through Maryland avenue, Oliver, Cathedral and Preston streets to Madison avenue, varying in diameter from 5 feet 9 inches to 3 feet.

The Dolphin Street Lateral enters this drain at Oliver and Cathedral streets and runs thence through Oliver street, Mt. Royal avenue and Dolphin street to Linden avenue, with diameters of from 4 feet to 1 foot 8 inches.

XV. *The Maryland Avenue Drain* empties into Jones' Falls just west of Charles street, and follows Morton alley, Oliver street, Maryland avenue and Mt. Royal avenue to Cathedral street. It is 4 feet 6 inches in diameter.

XVI. *The Charles Street Drain* runs in that street from Jones' Falls to Mt. Royal avenue, draining a district bounded on the south by Biddle street, and is 3 feet and 2 feet 9 inches in diameter.

XVII. *The Read Street Drain* runs from Jones' Falls through Read street to Cathedral street, varying from 4 feet to 20 inches in diameter, the outlet for nearly 600 feet being a 40-inch cast iron pipe.

A short lateral extends in Morton alley to Madison street.

XVIII. *The Centre Street Drain* extends in that street from Jones' Falls to St. Paul street, the drainage area extending as far as Eutaw and Madison streets. The section below North street is an arch culvert 8 feet wide and 4 feet 8½ inches high, while above this point the form is that of an arch culvert 4 feet wide and 4 feet 3 inches high. The section below Holliday street is not known.

XIX. *The Bath Street Drain* runs from Jones' Falls up Bath, Calvert and Franklin streets to near Courtland street. It has sections of from 8 feet by 5 feet to 4 feet 6 inches by 3 feet.

A 4 foot by 2 foot 6 inch lateral runs from Bath and Calvert streets through the latter and Mulberry street to near Courtland street.

XX. *The Saratoga Street Drain* discharges into Jones' Falls north of Gay street, and runs up Saratoga street to Calvert. The diameter is 3 feet, and the grade about 0.5 per cent.

XXI. *The Cross Street Drain* empties into the Harbor at the foot of Cross street, and runs thence through a tunnel under Cross street to Light street, and thence to Warren avenue, with a

segmental arch culvert at the outlet and diameters of 5 feet 9 inches on Cross street and 4 feet on Light street.

A lateral extends from Cross and Light streets on Light street, West street and Battery avenue to Clement street, varying from 4 to 2 feet in diameter.

XXII. *The Fort Avenue Drain* discharges into the Middle Branch at the foot of that avenue, and runs thence easterly to Light street, with diameters of 5 feet, 3 feet 6 inches and 3 feet.

XXIII. *The Race Street Drain* runs from the Middle Branch at Spring Gardens through private property to Stockholm, Race, Cross and Charles streets. It is a segmental arch culvert 11 feet wide by 8 feet high below West street, and 11 feet by 3 feet 6 inches above that street.

XXIV. *The Howard Street Drain* discharges into Spring Gardens at the foot of Howard street, and runs through Howard, Liberty, Park, Lexington and Howard streets to Mulberry, with sizes varying from a 7 foot 6 inch by 4 foot 6 inch ellipse to a 2 foot 9 inch circle.

The Pratt Street Relief Drain discharges into the Basin at Light street, and runs west on Pratt street to Howard, where it taps the Howard Street Drain. It is 3 feet in diameter.

XXV. *The Chatsworth Run System* consists, in general, of drains running from Columbia and Fremont avenues (1) up Fremont avenue to Saratoga street and (2) up Penn, Arch, Pearl and Tessier streets to Biddle street, with two outlets from the same point, one continuing down Fremont avenue and Eutaw street to the Middle Branch of the Patapsco, and the other west of, and approximately parallel to Paca street to Scott and through Alluvion street—whence it is known as the Alluvion Street Drain—to its mouth at the Middle Branch. The entire system drains an area of about 740 acres—410 acres above the intersection in Columbia and Fremont avenues and 330 acres below.

1. The Fremont Street Lateral drains about 107 acres and varies from an 8 foot by 4 foot 10 inch to an 8 foot by 4 foot 6 inch horizontal ellipse in section.

2. The Penn Street Lateral is in section a segmental arch over a nearly rectangular box as far as Arch and Baltimore streets, then an ellipse to Pearl street south of George, and the balance a circle, the cross-sectional areas of which vary from 106 to 16 square feet.

The Pine Street and Pennsylvania Avenue Branch leaves the

Penn street lateral at German street and runs through German, Pine and Saratoga streets, Myrtle avenue and Greenwillow street, Shields alley, Hoffman street and Pennsylvania avenue to Lafayette avenue, varying from a 6 foot by a 5 foot ellipse to a 3 foot circle in size.

3. The Eutaw Street Outlet varies from a 12 foot by 8 foot box culvert to a 9 foot 3 inch circle.

4. The Old Chatsworth Run Outlet, or that in Scott and Alluvion streets, is in form a segmental arch spanning a nearly rectangular channel. It varies in section from 20 feet by 7 feet 9 inches to 15 feet by 6 feet 4 inches.

XXVI. *The Schroeder Run System* drains nearly 900 acres lying in general east of Monroe and south of Presstman streets and adjoining the Chatsworth Run district on the west.

The main drain follows, in general, the following course from its outlet at the Middle Branch, viz.: through Bush, Herkimer, Carey, Franklin and Calhoun streets to Mosher. It is next to the Harford Run Intercepting Drain in size as well as in area drained. It consists at the outlet—where it is known as the Bush Street Drain—of a segmental arch with a 5 foot rise over a channel 25 feet wide and 4 feet high, diminishing to a 7 foot circle at Carey and Ramsay streets and a 4 foot 6 inch circle for the portion on Calhoun street.

1. The Old Schroeder Run Lateral leaves the main drain at Ramsay street, runs northeasterly under the B. & O. R. R. shops and other private property to Lombard and Schroeder streets, to Baltimore street, and northwesterly to Mulberry and Carey streets. It is, in general, a segmental arched culvert varying from 14 feet 3 inches in width by 9 feet in height to 8 feet by 5 feet.

2. The Calhoun Street Lateral also branches from the main drain at Ramsay street and runs up the latter and Calhoun street to a point in Lanvale street. Branches to the west occur on Baltimore, Saratoga and Franklin streets, extending to Gilmor street. The Franklin street branch continues up Gilmor street to Edmondson avenue. Their sizes are as follows:

Calhoun Street Lateral, 7 ft. diam. to 4 ft. 9 in. diam.

Baltimore Street Lateral, 4 ft. diam. to 3 ft. 6 in. diam.

Saratoga Street Lateral, 2 ft. cast iron pipe.

Franklin Street Lateral, 2 ft. cast iron pipe.

3. The Fulton Avenue and Eagle Street Lateral empties at present into Carroll's Run near the northeast corner of Carroll Park,

and extends in Ohio avenue, Fulton avenue, Eagle street and Monroe street to Ramsay street, with diameters of 5 feet 9 inches to 3 feet 6 inches. It drains about 122 acres.

A branch of this continues up Fulton avenue from Eagle street to Ramsay street, with diameters of from 3 feet 4½ inches to 2 feet 6 inches.

XXVII. *The Franklin and Pulaski Streets Drain* serves as an outlet for the drainage of some 600 acres lying to the west of Fulton avenue, that is as yet but sparsely built up. It empties into a small stream in Smallwood street 130 feet south of Franklin street, and runs in Smallwood, Franklin, Pulaski and Lanvale streets into Brice alley, with diameters of 11 feet and 10 feet 6 inches.

Beginning again at a stream in Baker street, west of Baker Circle, the drain continues to Fulton avenue to Presbury street and in Bruce alley to and across North avenue, with diameters of 8 feet 9 inches and 8 feet.

XXVIII. *The Tiffany Run Drain* was built by the Water Department to divert the drainage of this run from the embankment of Lake Montebello, and takes the storm water from about 1,000 acres, 500 of which lie outside the city limits, but all of which are rural in character, to an outlet in Herring Run. From the latter point the drain runs near the north side of Lake Montebello, intercepting the flow from several small watercourses, and terminates at the Hillen Road, being 9 feet in diameter throughout.

2. ADEQUACY OF THE EXISTING DRAINS.

The following is a summary of results found as to the adequacy of the present drains to discharge the flow-off of extreme down-pours, under the supposition that the drainage area is well built up and paved—a condition which it is assumed will obtain in the future, as it already does in most cases.

Some instances are also given where excessive velocities will occur in the drains running full or half full. With the steep slopes occurring in many parts of the city the grade of the drain, unless broken by drop-wells or stepping, produces such currents during hard storms that a comparatively small obstruction or weak detail in the structure, such as a piece of board or a few displaced bricks, may readily cause bursting or collapse. Under such conditions, when a rupture takes place, great damage may occur to the adjacent property as

well as to the drain. Such cases have not been infrequent in the past.

The following drains have been found of inadequate capacity when running full.

a. The Harford Run Intercepting Drain (I). The section 3,267 feet in length from the outlet to the Ogier Run Lateral, having grades of 0.138 per cent. and 0.300 per cent., and which drains over 1,700 acres, as well as a section 418 feet in length and 8 feet in diameter just below Oliver street, with grades of 0.100 per cent. and 0.237 per cent., may both be expected to run more than full during heavy downpours under existing conditions. When, however, this watershed is more densely built up nearly all of this drain below Oliver street will require relief. This may be provided by a drain from the foot of Patuxent street to Eastern avenue, and from thence northeasterly, intercepting the flow-off from, and north of, Highlandtown.

Above Oliver street the capacity appears ample.

The Ogier Run Lateral (1) with a grade of 0.513 per cent., will have but about one-half the required capacity when its tributary area is built up. The drain proposed above in Patuxent street for the relief of the main drain may be designed so as to intercept as much drainage as is necessary from this lateral.

b. The Jenkins Run Drain (IX) from Girard avenue to a point in Greenmount avenue 174 feet south of North avenue, having cross sections of 65 and 49 square feet and grades of from 1.04 per cent. to 0.22 per cent., is of insufficient capacity.

c. The Division Street Lateral of the North Avenue and Druid Hill Avenue Intercepting Drain (XII). From Division street 70 feet north of Bloom street this is 3 feet in diameter and has grades of from 2.12 per cent. to 0.77 per cent. It is too small to provide for its tributary area, but may be relieved by a lateral up Division street.

d. The Howard Street Drain (XXIV) receives the flow-off from about 200 acres. It is inadequate below Hamburg street, but this section is relieved by an emergency drain outlet through Pratt street.

From Wayne street to Fayette street it is 5 feet and 4 feet 6 inches in diameter, with grades of from 1.08 per cent. to 0.84 per cent., and is of inadequate size for exceptional storms.

e. The Pine Street and Pennsylvania Avenue Branch of the

Penn Street Drain (Chatsworth Run System, XXV) from Shields alley and Hoffman street to Pennsylvania avenue and Lanvale street is of too small capacity. It varies from a 6 foot by 4 foot ellipse with a 0.90 per cent. grade to a 4 foot circle with a 1.25 per cent. grade.

f. The main drain of the Schroeder Run System lying in Calhoun street from a point about 400 feet north of Franklin street to Lanvale street is 4 feet 6 inches in diameter, has grades of 1.388 per cent. and 1.25 per cent., and drains about 130 acres. It is of too limited capacity.

In addition to the above list there are many drains whose capacity is open to question, but, depending on the smoothness of their interior, the precise area draining to them and the method of collection, they may prove adequate.

The following are lists of inadequate drains, and those of questionable adequacy, general descriptions of which may be found in Section 1.

POINTS AT WHICH PRESENT DRAINS HAVE INADE- QUATE CAPACITY FOR CITY CONDITIONS.

Drain.	Location.	Size.	Area sq. ft.	Mean Radius.	Hydraulic Slope.	Present capacity cu. ft. per sec. full.	Acres drained.	Average slope per 1000.	Eventual run-off cu. ft. per sec.
I.	Boston St	24' x 9' 6"	187	3.17	0.138	1550	1960	30	2210
	Canton Ave	24' x 9' 6"	179	3.08	0.138	1460	1870	30	2150
	Ogier Run Junction	17' x 9' 6"	134	2.90	0.300	1580	1710	30	2000
	Baltimore St	10' diam.	78	2.50	0.628	1320	1025	30	1330
	Patapseo St. and Monu- ment St	10' "	78	2.50	0.354	980	888	30	1170
	Burke St	10' "	78	2.50	0.256	840	688	30	970
	Oliver St.	8' "	50	2.00	0.237	440	457	30	690
	Ogier Run Lat. Patterson Park	7' "	38.5	1.75	0.513	460	612	25	850
IX.	Girard Ave.	10' x 10' 2"	65	1.85	1.105	1152	800	50	1210
XII.	Division St. and Gold St.	3' diam.	7.1	0.75	2.122	97	48	25	110
	Gold St. and Penna. Ave.	3' "	7.1	0.75	1.270	75	34	25	85
XXIV.	Cross St.	7' 6" x 4' 6"	26.5	1.38	0.432	249	180	20	305
	Hamburg St.	7' 6" x 4' 6"	26.5	1.38	0.519	270	175	25	310
	Lombard St. and Liberty St.	5' diam.	19.6	1.25	0.650	213	110	30	225
	Baltimore St.	4' 6" diam.	15.9	1.13	0.944	192	93	40	205
	Fayette St.	4' 6" "	15.9	1.13	0.844	182	81	40	186
XXV.	Shields Al. and Hoffman St.	6' x 4'	15.7	0.99	0.900	176	102	25	203
	Penna. Ave. and Hoff- man St.	4' diam.	12.6	1.00	1.250	162	94	25	192
	Penna. Ave. and Lanvale St.	3' "	7.1	0.75	1.190	72	50	25	115
XXVI.	Calhoun St. near Edmond- son Ave.	4' 6" diam.	15.9	1.13	1.388	233	131	30	255

LIST OF DRAINS OF QUESTIONABLE ADEQUACY.

Drain No.	From	To	Capacity cu. ft. per sec.	
			From	To
I.	Ogier Run	400' above Ogier Run.	1500	
	Eager Street	Chase Street.	760	
II.	Outlet	Alieeanna Street.	120	80
	Gough Street	Wolfe Street and Fairmount Ave.	135	67
IV.	Central Ave. S. of Eastern Ave.	Eden St. and Pratt St.	111	84
	Central Ave. and Jefferson Street	McElderry Street.	80	87
	Orleans St. and Eden St.	Bond Street.	39	39
III.	Outlet	Eastern Ave.	86	
XII.	Druid Hill Ave. and Laurens Street	Between Robert and Presstman Streets.	256	284
XX.	Outlet	Calvert Street.	47	
XXVI.	Calhoun St. near Edmondson Ave.	Calhoun St. and Lanvale St.	222	

On the other hand, a number of drains have been built of a capacity which would seem unwarranted from the areas tributary to them. Of these may be mentioned the following:

DRAINS OF EXCESSIVE CAPACITY.

Drain No.	Location.	Size.	Area sq. ft.	Mean Radius.	Hydraulic Slope.	Present capacity cu. ft. per sec., full.	Acres drained.	Ave. slope per 1000.	Eventual run-off cu. ft. per sec. assuming $r = 4$.
I.	Eager St. E. of Ann St.....	8' diam.	50.3	2.00	0.289	490	55	20	134
	Ann St. & Chase St.....	7' 6'' diam.	44.2	1.88	0.266	400	53	25	136
	Gay St. 50 ft. E. of Ann St.....	5' 9'' diam.	26.0	1.44	0.773	336	46	30	126
IV.	*Watson St.....	16'x6'	77.4	1.95	1.948	1840	299	30	568
	Hampstead St....	16'x6'	77.4	1.95	0.923	1275	290	30	555
	Nicholson Alley..	15'x7'	83.0	2.18	1.007	1540	285	30	542
	Eden Street above McElderry St..	10'x6'	47.0	1.84	1.244	885	128	30	290
	Madison St. & Car- oline St.....	6' 6'' diam.	33.2	1.62	0.734	460	70	30	180
	Bond St. & Abbott St.....	6' 6'' diam.	33.2	1.62	0.541	395	52	30	142
	W. S. Broadway..	12'x6' 6''	63.8	1.96	0.735	955	44	25	118
	Ann St. & Eager St.	7' 6'' diam.	44.2	1.88	0.266	400	22	25	68
XI.	Lanvale St.....	5' 6'' diam.	23.8	1.38	2.000	483	71	25	174
XIII.	McMechen St. W. of Bolton St....	4' 9''x8'	31.6	1.44	2.052	666	116	25	257
XVII.	Centre St. & Cal- vert St.....	4'x4' 3''	15.6	1.04	3.671	363	64	60	147
XXIII.	Leadenhall St....	11'x8'	77.0	2.29	0.250	730	100	15	206
XXV.	Penn St. & Haw St.....	18'x7' 3''	106.2	2.39	0.750	1795	345	25	620
	Penn St. & Lom- bard St.....	16'x8'	104.7	2.51	0.945	2017	328	25	594
	German St. & Arch St.....	18'x7' 3''	105.0	2.41	1.000	2048	127	32	297
XXVI.	Bush St. & Ham- burg St.....	25'x9'	184.0	3.04	0.500	2884	825	30	1262
	Carey St. & Lom- bard St.....	7' diam.	38.5	1.75	2.500	1030	181	30	380
	Fulton Ave. & Ram- say St.....	3' 4½''x2' 6''	7.1	0.74	2.678	114	5±	45	23

* The run-off to this drain has been partly cut off, since its construction, by the Harford Run Intercepting Drain (I).

Note: From what is known of a few of the drains, it is assumed that the interior finish of them in this table will warrant the use of a coefficient of roughness approximating .013. If, however, they should have an interior surface warranting a coefficient of roughness equal to 0.015 they would still be of excessive capacity. If of yet inferior finish, a few of the list may prove to be not excessive in capacity.

It will be noticed that in these tables the capacity of the drain is given when running full. To avoid the likelihood of rupture in case of accidental obstruction or possible weakness the drain should be designed to run but partly full, but an allowance of 50 per cent. above the calculated capacity is deemed sufficient for any ordinary case. It will also be seen that in the list of drains of excessive capacity a rate of rainfall of 4 inches per hour has been assumed instead of $3\frac{1}{2}$ inches.

MISCELLANEOUS NOTES REGARDING THE CAPACITIES OF DRAINS.

If the Broadway Drain (II) should be found inadequate it may be relieved by a drain on Wolfe street or Washington street intercepting the flow from the east.

The precise areas intended to be drained by this and the Eden Street Drain (III) are not known, but if the latter is expected to take the flow-off from the west of the Broadway Drain, it is too small. Probably a part of this flows beyond to the Central Avenue Drain.

The Central Avenue Drain (IV), built at various times, is a good illustration of the result to be expected where such a structure is designed and built piecemeal by different persons, with no unity either in the assumed conditions to be met or in the method of dealing with them.

For instance, if equally well built, the following conditions exist:

At Pratt street the capacity is 690 cubic feet per second, with a velocity of 10 feet per second.

At Watson street the capacity is 1,840 cubic feet per second, with a velocity of 24 feet per second.

Above Hampstead street the capacity is 720 cubic feet per second, with a velocity of 11 feet per second.

At Nicholson street the capacity is 1,540 cubic feet per second, with a velocity of 18 feet per second.

At McElderry street the capacity is 275 cubic feet per second, with a velocity of 6 feet per second.

100 feet below Monument street the capacity is 885 cubic feet per second, with a velocity of 19 feet per second.

At Bond street the capacity is 395 cubic feet per second, with a velocity of 11 feet per second.

Between Abbott street and Broadway the capacity is 955 cubic feet per second, with a velocity of 15 feet per second.

It will be at once seen that large sums of money may be virtually thrown away for want of the intelligence necessary merely to limit the capacity of the extension of a drain to that of the section already built below it.

The laterals to this drain which have been mentioned as possibly inadequate, may, should they prove so, be relieved by allowing portions of their collection areas to drain directly to the main drain, as is possibly the case now, to a certain extent.

The inadequate section of the Jenkins Run Drain (IX) may be relieved by carrying the lateral in Greenmount avenue under the main drain and down Greenmount avenue to a junction with it at Girard avenue, below which its capacity is ample.

The North Charles Street Drain (XI) is perhaps intended to supplant the Lovegrove Alley Drain, which was built a long time ago and may be insecure, or it may be intended to intercept the headwaters of Sumwalt Run by tunnelling the summit at Twenty-ninth street; otherwise the capacity of this drain is largely in excess of its requirements, having but a narrow strip west of the Lovegrove alley drainage area to provide for.

The Druid Hill Avenue Drain (XII) appears of barely sufficient capacity for the first 630 feet (being less than 25 per cent. of the section immediately below in McMechen street), but if in good condition this drain may serve for the present, and when necessary it can be supplemented by a drain in McCulloh street.

The Rutter Run Lateral (XIII) now serves but a small area to the west of the Mt. Royal reservoir. If necessary, it may be extended so as to relieve the main drain.

It is not known why the Maryland Avenue Drain (XV) was built of so great capacity, as the area above its upper end is served by the drain in Preston street; or, if built first, why it was not utilized as an outlet for said drain.

Drain XIX is excessive in capacity, but as the elements of its design are not obtainable, it was not included in the foregoing table.

The Pratt Street Relief Drain (XXIV) is of proper capacity to afford an outlet for such extreme discharges as the main in Howard street will not accommodate, but is inadequate to serve as well for the disposal of the storm water of its own area.

The Eutaw street outlet of the Chatsworth Run System (XXV) would, if well built and clean, be nearly adequate to take the flow-off of the entire Chatsworth Run district. It is, however,

relieved by the Old Chatsworth Run or Scott street outlet, which, too, under similar conditions, would be of nearly adequate capacity for the purpose.

The Old Schroeder Run Lateral (XXVI) having been intercepted by the main drain in Carey street, its capacity is largely in excess of requirements.

The Tiffany Run Drain (XXVIII) is of proper capacity, assuming, as seems reasonable for this district, that but about 50 per cent. of the storm water flows directly to the drain.

There remains for consideration the question of the velocities occurring during times of flood. Extreme normal velocities cause a gradual erosion of the invert by the transport of sand and other detritus, while extreme maximum velocities may lead, in addition, to sudden and extensive breaks. Such maximum velocities should not exceed 16, or at most 18, feet per second. Assuming the drain to run full or half full, there would result in

- | | | |
|-------|--------|--|
| Drain | I. | Federal Street Lateral, velocities up to 19 feet per second. |
| " | IX. | Lower end to above Oliver street, velocities of 20 feet per second. |
| " | X. | Union Station to Adams street, velocities approaching 30 feet per second. |
| " | XI. | Below Lanvale street, velocities up to 20 feet per second. |
| " | XIII. | Outlet to near Eutaw Place, velocities of 19 to 24 feet per second. |
| " | XXV. | Penn Street Lateral, Columbia avenue to Baltimore street, velocities of 17 to 24 feet per second. |
| " | XXVI. | Hamburg street to B. & O. R. R. shops, velocities of 17 to 27 feet per second. |
| | | Ramsay street to Fayette street, velocities of 18 to 26 feet per second. |
| | | Franklin street, Carey street to Calhoun street, velocities of 17 feet per second. |
| | | Lanvale street to Mosher street, velocities of 17 feet per second. |
| | | Carey street and Ramsay street to Calhoun and Lanvale streets, velocities of 16 to 22 feet per second. |
| " | XXVII. | Smallwood street to Brice alley, velocities of 20 to 22 feet per second. |

It is to be understood that in those drains having either a rough interior surface or such a capacity that they never run half full, the velocities named may never obtain, but there can be no doubt that nearly all the above are subject to higher velocities than should be permitted.

3. SUGGESTIONS AS TO THE IMPROVEMENT OF IMPROPERLY DESIGNED DRAINS.

Aside from the stability of the structures, which is not here considered, the more serious faults in design are those which result (1) in inadequate capacity, resulting in a gorging of the drain and an overflow upon adjacent premises; (2) excessive capacity, resulting in unnecessary cost of construction and, combined with low gradients, in small velocities causing deposits of silt, etc.; (3) excessive velocities, resulting in undue erosion of the invert and in possible rupture during floods.

Where the capacity is inadequate, drainage from a part of its area of collection may be intercepted and led to a point below the inadequate section, or directly to an independent outfall.

The unnecessary expense incurred on drains of excessive capacity cannot, of course, be recovered; but where deposits are found to occur the flow may be improved by giving the invert a new and smooth lining of vitrified brick, or by building a new invert of semi-circular or oval section inside the old one, to concentrate the flow and hence increase the scouring action.

3. Excessive velocities will be difficult to avoid without entire reconstruction, increasing the friction by using flat inverts and introducing drop-wells or steps to break the current. Excessive erosion of the invert may be remedied by relining with granite blocks or by the use of cast iron invert plates.

Yet another defect exists in the Baltimore drains, and should receive attention until sewage proper is no longer admitted, namely, the discharge of offensive gases from inlets. This occurs, at its worst, at the upper ends of drains, especially those having steep slopes, and depends largely on the relative temperatures in the drain and of the outside air and on other meteorological conditions.

A partial remedy by increasing the dispersion of these gases may be had by hanging gates or flaps in the drains at changes of grades and junctions which will swing freely by the flow of the drainage downstream, but will nearly close by air currents ascending the drain, thereby forcing them through the manholes to the outer air.

Ventilation through manhole covers should be as free as possible, and undue deposits of sediment should be removed by hand or by flushing.

It is, moreover, recommended that as a matter of safety, wherever inlet openings exceed six inches in height, suitable bars or gratings be provided as a protection to life.

B.—EXTENSIONS TO THE PRESENT DRAINAGE SYSTEM.

The existing drains built by the city aggregate about 33 miles in length, cost some \$4,000,000, and provide outlet for nearly 13 square miles of territory, or about two-fifths of the entire area within the city limits. This includes the greater part of the more densely populated districts.

The following well built-up areas remain unprovided for:

1. An area roughly described as lying between the Basin, Montgomery, Sharp, Fayette, Front, Baltimore, Lloyd and Stiles streets and Jones' Falls.

2. An area lying between that tributary to the Broadway Drain (II) and Patterson Park.

3. Certain areas near Riverside Park.

4. Certain areas in and about Woodberry.

These will all require provision in the near future.

The greatest outlay, however, will be required in developing the drainage systems already begun, and may, in brief, be best accomplished by the construction of laterals, usually of small dimension, from two to four blocks apart at right angles to the main drain. Such an arrangement will avoid large laterals in deep excavation which might interfere with the proposed network of sewers, and by providing frequent inexpensive inlets the carriage of storm water for long distances by the gutters, with its objectionable features, will become unnecessary.

Areas lying adjacent to tidewater and the natural lines of drainage, such as Jones' Falls, Gwynn's Falls or Herring Run may, perhaps, be best served by short drains discharging directly into these whenever it becomes objectionable to permit the storm water longer to find its way over the surface. These drains, serving but limited areas, will not be important as to size, and may usually be built as found necessary without reference to those serving other districts.

But among the more populous outlying areas remaining unpro-

vided for, four, with their probable main lines of collection, may be briefly noted as follows, viz.:

1. An area lying to the west of the Old York road, Twenty-ninth street and Maryland avenue, finding an outlet to Jones' Falls by way of Sumwalt Run.

This drains about 575 acres to a point opposite the Mt. Royal reservoir, where its outlet would require a capacity, when two-thirds full, of 1,000 cubic feet per second.

2. An area draining to Stony Run lying west of the Sumwalt Run watershed and east of Roland avenue in Hampden, and containing about 2,100 acres, 518 of which lie within the city limits.

Following the valley of Stony Run this would discharge into Jones' Falls opposite Druid Hill Lake with a capacity, when two-thirds full, of 2,900 cubic feet per second.

3. An area draining to a valley just north of Druid Hill Park with a watershed area of 354 acres. This will require a drain with a capacity of some 700 cubic feet per second when two-thirds full, and will discharge into Jones' Falls near Union avenue.

4. An area draining to a small run just southeast of Druid Hill Park, containing about 109 acres. A drain for this district will discharge into Jones' Falls opposite Stony Run, with a capacity, two-thirds full, of about 230 cubic feet per second.

These four main drains will furnish outlets for the drainage from the 2.4 square miles of well built-up area lying within the annexed district that are as yet unprovided for excepting Walbrook, Irvington and Calverton, which may drain directly to Gwynn's Falls or to Gwynn's Run.

The true functions of the city's drains are: 1st, to carry the storm water from street inlets to its final point of discharge as quickly and directly as possible, avoiding in this way its carriage for any great distance over the surface. 2d, to provide a means for such drainage of the subsoil and cellars as may be necessary to effect a sanitary condition thereof, a saturated soil or damp basement being especially favorable to the dissemination of malarial, pulmonary and diphtheritic troubles. 3d, to take such liquid manufacturing and other wastes as may be permissible without danger of deposit, putrefaction or other nuisance while in, or after leaving, the drain. Whatever may be removed in this way will relieve the sewers of that duty to a corresponding extent. Connections for the above purposes should be made only by special permission, by and under the direct supervision of the City.

On the other hand, to ensure a sanitary and economical operation of a system of storm-water drains, it is essential that the admission thereto of house sewage or the overflow from cesspools, the drainage of putrescible liquors from slaughter-houses or other establishments, garbage or other solid matters be absolutely prohibited. A certain amount of silt or street washings will undoubtedly find entrance by way of the inlets, but by a proper construction and administration of these the amount entering will be small, inoffensive and readily removed.

Respectfully submitted,

KENNETH ALLEN,

Principal Assistant Engineer.

LIST OF RAINFALLS OF GREAT INTENSITY OCCURRING
IN BALTIMORE IN RECENT YEARS, FROM THE
RECORDS OF THE WEATHER BUREAU.

The storms marked by a star (*) were recorded by automatic gauges.

	DATE.	Amount in Inches.	Duration, Hrs. Min.	Rate in inches per Hour.
May	21, 1897.....	.57	5	* 6.84
July	21, 1896.....	.05	$\frac{1}{2}$	* 6.00
June	16, 1896.....	.10	1	* 6.00
July	17, 1897.....	.80	10	* 4.80
June	16, 1896.....	.35	5	* 4.21
Sept.	19, 1896.....	.35	5	* 4.20
May	21, 1897.....	.67	10	* 4.02
July	17, 1897.....	1.00	15	* 4.00
June	16, 1896.....	.45	7	* 3.85
Sept.	19, 1896.....	.95	15	* 3.80
May	6, 1894.....	.25	4	* 3.75
July	27, 1896.....	.30	5	* 3.60
July	21, 1896.....	.30	5	* 3.60
April	27, 1890.....	.80	15	3.20
July	21, 1896.....	.25	5	* 3.00
July	9, 1896.....	.10	2	* 3.00
May	21, 1897.....	.70	15	* 2.86
July	17, 1897.....	1.19	25	* 2.80
Sept.	19, 1896.....	1.00	22	* 2.73
July	21, 1896.....	.45	10	* 2.70
Sept.	8, 1879.....	1.32	30	2.64
July	7, 1896.....	.41	10	* 2.46
July	27, 1896.....	.38	10	* 2.28
Sept.	19, 1896.....	1.09	31	* 2.11
March	22, 1890.....	.17	5	2.04
August	10, 1897.....	.17	5	* 2.04
July	9, 1896.....	.05	$1\frac{1}{2}$	* 2.00
July	8, 1888.....	.96	30	1.92
June	23, 1888.....	1.10	35	1.89
July	7, 1896.....	.50	17	* 1.76
May	21, 1897.....	.72	25	* 1.72
August	21, 1890.....	1.96	1 10	1.68

DATE.		Amount in Inches.	Duration, Hrs. Min.		Rate in inches per Hour.
May	6, 1894.....	.40	15		* 1.60
July	22, 1897.....	.21	8		* 1.57
August	10, 1897.....	.52	20		* 1.56
August	22, 1887.....	1.74	1	10	1.49
July	5, 1895.....	.99	40		* 1.48
May	6, 1894.....	.60	25		* 1.44
August	5, 1888.....	.48	20		1.44
August	10, 1897.....	.68	30		* 1.36
July	30, 1889.....	1.01	45		1.35
August	10, 1873.....	1.30	1		1.30
July	9, 1896.....	.15	7		* 1.29
June	22, 1892.....	1.23	1		1.23
July	9, 1896.....	.11	5		* 1.21
July	21, 1896.....	1.20	1		* 1.20
May	20, 1889.....	1.20	1		1.20
June	23, 1888.....	1.18	1		1.18
June	4, 1891.....	1.15	1		1.15
August	5, 1888.....	1.12	1		1.12
August	10, 1897.....	.79	45		* 1.05
August	8, 1888.....	1.03	1		1.03
June	8, 1881.....	1.16	1	10	1.00
July	9, 1896.....	.20	14		* .86
Sept.	6, 1895.....	1.60	2		* .80
August	30, 1895.....	.78	1		* .78
May	23, 1894.....	.75	1		* .75
Sept.	6, 1895.....	2.20	3		* .73
August	10, 1897.....	.89	1	20	* .67
July	16, 1895.....	.66	1		* .66
Sept.	19, 1895.....	.61	1		* .61
July	30, 1896.....	.10	10		* .60
July	27, 1896.....	.56	1		* .56
May	20, 1894.....	.55	1		* .55
July	9, 1896.....	.16	20		* .48
Jan.	26, 1895.....	.45	1		* .45
Dec.	26, 1895.....	.45	1		* .45
Sept. 5 and 6,	1891.....	4.00	9	10	.44
June	16, 1896.....	1.17	2	43	* .43
Sept.	6, 1895.....	3.74	10	40	* .35
Sept.	6, 1895.....	4.76	16	30	* .29

DATE.	Amount in Inches.	Duration, Hrs. Min.	Rate in inches per Hour.
June 28, 1885	4.47	24	.186
August 13 and 14, 1873.....	4.36	24	.182
February 5 and 6, 1896.....	3.48	20	.17
July 30 and 31, 1889.....	4.02	24	.167
September 16 and 17, 1876.....	3.94	24	.164
July 11, 1884.....	3.75	24	.156
July 20, 1880.....	3.71	24	.154
July 1 and 2, 1889.....	3.63	24	.151
April 25, 1889.....	3.58	24	.149
March 8 and 9, 1881.....	3.51	24	.146
October 23, 1890.....	3.04	23 15	.13
July 8, 1891.....	2.59	24	.11

The Monthly Weather Review for January, 1897, published by the U. S. Weather Bureau, contains the following maximum rates of downpour for various intervals of time as observed at Washington, D. C., during the past 16 years:

DATE.	Time, Consecutive Minutes.	Rate in Inches per Hour.
September 3, 1882	5	7.50
September 16, 1888.....	10	5.10
June 27, 1881.....	15	4.50
June 27, 1881.....	20	3.90
June 27, 1881.....	25	3.60
June 27, 1880.....	30	3.15
June 10, 1876.....	40	2.75
June 10, 1876.....	50	2.30
June 10, 1876.....	60	1.98
July 26, 1886.....	120	1.23

APPENDIX C

REPORT ON SYSTEMS OF

SEWERAGE AND DRAINAGE

FOR THE

CITY OF BALTIMORE

JOINTLY PRESENTED BY
RUDOLPH HERING and SAMUEL M. GRAY
Consulting Engineers

NEW YORK AND PROVIDENCE

November, 1896

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REPORT OF CONSULTING ENGINEERS.

NEW YORK AND PROVIDENCE, *November, 1896.*

MENDES COHEN, Esq., F. H. HAMBLETON, Esq., E. L. BARTLETT, Esq.,	} Sewerage Commission of the City of Baltimore.

Gentlemen:—In accordance with your letter of April 16, 1895, containing an outline of the services we are expected to render to your Commission, in recommending a plan for the collection and disposal of the sewage of your city, together with its estimated cost, and a thorough discussion of the subject, the present report is herewith respectfully presented.

A

INTRODUCTORY REMARKS.

At a joint meeting with yourselves, it was decided that we were to be at liberty to consult with each other regarding your work, but that we should give to you our individual opinions concerning our recommendations.

Since starting upon our labors, such consultations have been frequent and a number of visits to Baltimore have been made, jointly and separately. To aid us in doing our work, you have furnished each of us copies of necessary maps, reports, and the results of surveys and borings, made at our request; and in numerous conversations on the subject you have given us much information on local questions.

Personal examinations of all the important parts of the territory have been made, either alone or with yourselves, or with Mr. Kenneth Allen, your assistant.

The lines of the possible main interceptors have been examined; also the territory lying between the Back River and the Patapsco River, with reference to clarifying the sewage and also with reference to discharging it into Chesapeake Bay off North Point; also

the land lying north and east of Back River; also the land lying south of Curtis Bay, as far as Magothy River, with reference to treating the sewage by filtration.

We have understood it to be the desire of your Commission to have an exhaustive enquiry made regarding the whole subject, so far as the general features of the problem are concerned, with a view to establish a comprehensive system of sewerage and drainage which will answer, practically, for all time.

Such a system you desired to be fully indicated in general outline, with its main features, so that it could be well comprehended, and its approximate cost ascertained.

Any detailed features, dependent upon minor conditions, and allowing some variations to be made when adapted to local requirements, must be given with the understanding that they should be so adapted, when it is decided to construct the works.

The assumptions regarding the requirements of the work have been liberal, but have been approximate only, which we consider sufficient for the present purpose. Later, when the works are to be constructed, the assumptions will need adjusting, and the many details will need to be carefully worked out.

Enquiry has been made with reference to these requirements, as presented to us, and the results are set forth in what follows:

B

OBJECT TO BE OBTAINED.

The necessity of a well-devised system of modern sewerage for a city of such magnitude and importance as Baltimore, requires no comment from us. It may be well to state, however, that the success of a system of sewerage depends, in a great measure, upon the carefulness with which it is designed and built, and upon the faithfulness with which the works are managed when in operation.

One advantage of a modern system of sewerage consists in removing all foul liquids in a proper manner and preventing them from running across the sidewalks and along the street gutters, as at present is customary in your city. The street gutters should be kept for the removal of rain-water only. Another advantage is, that all privies can be abolished and water-closets substituted. It is important that cesspools, as soon as superseded by sewers,

should be thoroughly cleaned and thereafter immediately filled with clean material.

The city is continually extending its built-up area, the population is increasing, and the demands for proper sewerage are becoming greater. When considering this question, it is therefore necessary to look into the future far enough to ensure that the system when complete will be not only sufficient for the demands of the population of the day, but will have such surplus capacity as to answer practically for all time, so far as it concerns the territory which the system is intended to cover.

It may be stated, that works of such importance as these, for the execution of which necessarily skill of a high order will be required, and which are to be built, practically as a whole, may be designed with a smaller allowance for contingencies, such as possible improper arrangements of details and improper workmanship, than if the work were to be done unsystematically, in small patches, at different times and by different officers. The economy, also, of building so large a work within a short time, and under the same management, will likewise be apparent.

It is evident that the character of the works recommended for sewerage and drainage depends first, upon the topographical and geological conditions of the territory; secondly, upon the sewers and drains already existing, and thirdly, upon the methods available for disposing of the sewage. To these matters, therefore, attention is now directed.

C

GENERAL TOPOGRAPHY AND GEOLOGY.

The City of Baltimore lies near the head of the Patapsco River, which, about ten miles below the city, discharges into the Chesapeake Bay. The River has two branches, the Northwest and Middle Branch, which extend several miles into the territory of the city, the main river passing westerly outside of the city. The main harbor, called the Basin, is situated at the head of the Northwest Branch. It is comparatively narrow and extends almost to the heart of the business districts.

The topography of the city itself is flat near the water, and rises somewhat rapidly towards the north and west, so that the

natural drainage of the city is good. The highest points within the city limits are situated in the northwest corner, where some territory rises above four hundred feet. The northeastern part of the city is not as high and the ground rises only to about three hundred feet above tidewater. In the southwest corner of the city it also rises to about three hundred feet. The total area of the city, including the water areas, is 32.21 square miles; excluding them, it is 29.54 square miles.

Several watercourses run through it. Jones' Falls, which is quite a stream, passes through the city near its centre, and discharges into the Northwest Branch. Gwynn's Falls, likewise a large watercourse, passes through the western part of the city, and discharges into the Middle Branch. Smaller streams, such as Gwynn's Run in the west, and Harford Run, Jenkins' Run and Stony Run in the north and east, and still others, break up the territory into numerous natural drainage areas, which eventually discharge into the two branches of the Patapsco River.

In the northeastern corner of your city, there remains a territory which does not drain into this river, but into Herring Run, and thence into the Back River. This territory therefore must receive a special consideration regarding its sewerage and drainage.

The excellent topographical survey of your city, prepared under the direction of Col. H. T. Douglas, and the model made in your office, very clearly show the physical characteristics of the territory.

In the suburbs there are numerous park areas which will remain uninhabited, and for which, practically, no provision need be made for sewage removal. These park areas, also, absorb a much larger proportion of the rainfall than do the built-up parts of the city.

The built-up territory is extending towards the higher ground in all directions, but mainly towards the north, and it is in this direction where also the greatest allowance must be made for future increase in the quantity of sewage and also for the run-off from heavy storms.

With reference to the subject of final sewage disposal, there is the large mass of water of the lower Patapsco River and Chesapeake Bay, into which the foul water might be discharged and diluted, and also the territory lying on each side of the river below the city, as Patapsco Neck, Marley Neck, etc., upon which it was thought the sewage might be purified.

A trip was made down the river into the Bay, and into Back River, in order to examine the surface conditions at the shores and the general currents of the water.

Patapsco Neck was carefully examined with reference to a possible treatment of sewage upon land, and also with reference to carrying an outfall sewer from the city near North Point. The special surveys and topographical maps made by Mr. Allen, show the character of this territory. Borings made in the lower portions of Patapsco Neck have indicated to us the character of its soil.

We also examined some of the territory on Back River Neck, in order to discover whether it was available for sewage treatment.

On the southwestern shore of Patapsco River, the territory was examined as far south as Magothy River, likewise with reference to the question of sewage disposal. A large number of borings five feet deep were made by Mr. Allen, showing the nature of that portion of the territory examined, which lies nearest the city. It was considered unnecessary, at present, to make closer examinations at more distant points, because the actual nature of the ground was generally apparent on the surface.

Hydrographic observations in the River and Bay were not made, because it appeared to be unnecessary to go to the expense of such observations in order to discuss the question of dilution.

The geological character of the ground, on which the city and its suburbs are located, has a bearing upon the construction of the sewers in the city, many of which will be deep; upon the disposal of sewage on land; upon the absorption of rain-water and its slow discharge into the streams by percolation; and also upon the present use of cesspools, into which foul liquids are discharged.

The character of the ground near the surface is generally clay, sand and gravel. Hence, excavations for sewerage purposes will not be unusually expensive. In the northern and western part of the city, and particularly in those sections which have not yet been built up, there will be some rock excavation. Rock crops out at the bottom of Jones' Falls above Eager street and also in the valleys of Gwynn's Run and Gwynn's Falls.

The territory of Patapsco Neck is largely covered with timber, and the soil consists mostly of loam, with occasional pockets of gravel and sand. In the southern portion of the Neck there is more sand than in the northern portion, but it is largely mixed with clay, and, therefore, its porosity is much decreased.

The soil near the surface of Back River Neck is quite similar, so far as an examination of the surface could determine. No extensive areas of sand or gravel are found in the higher territory northwest of these two necks. The soil immediately southwest of the city

is likewise mostly clay and loam, as far as Curtis Bay. At this latitude, however, the clay strata begin to be covered with sand which is more or less free from the admixture of clay.

Going in a southerly direction, the sand layers increase in thickness and in freedom from such admixture at least as far as Tick Neck, where there are large areas of almost pure sand at the surface.

The ground on both sides of Furnace Creek and its branches, while showing more or less sand a short distance below the surface, is covered with a layer of soil, in which vegetation flourishes.

A close reconnaissance of these sandy areas was made by Mr. Allen, and a map showing the topography has been prepared by him.

We are indebted to the kindness of Prof. Wm. Bullock Clark, State Geologist, for a brief report on the geology of the site of Baltimore, and of the region adjacent to the Lower Patapsco River, and present the same in the Appendix to this report.

D

POPULATION.

In designing a system of sewers, it is necessary to provide for it a capacity sufficient to answer not only the present, but also the future requirements of the population. In most cities there are certain parts which have already received their probable ultimate development, so far as density of population is concerned.

Cities usually grow more by adding to their territory than by increasing the population within the already built-up sections. The proposed system of sewers should therefore be capable of extension into all directions which will eventually be built up.

POPULATION OF BALTIMORE BY WARDS.

Ward.	Area in acres.	Population in 1896.		Estimated Population.	
		Total.	Per acre.	Total.	Per acre.
1	595.2	29,150	49	31,000	52
2	249.6	18,520	74	19,000	76
3	153.6	19,310	126	21,000	137
4	153.6	17,750	116	20,500	133
5	140.8	18,740	133	20,500	146

Ward.	Area in acres.	Population in 1896.		Estimated Population.	
		Total.	Per acre.	Total.	Per acre.
6	1,024.0	37,500	37	81,000	79
7	326.4	37,300	114	38,000	116
8	480.0	30,300	63	31,000	65
9	332.8	19,060	57	30,000	90
10	136.0	19,550	144	20,500	151
11	204.8	24,550	120	25,500	124
12	441.6	29,930	68	36,500	83
13	172.8	18,190	105	22,500	130
14	166.4	21,870	131	22,500	135
15	172.8	17,800	103	21,000	122
16	134.4	17,820	133	18,500	138
17	1,222.4	34,190	28	91,500	75
18	1,120.0	35,920	32	70,500	63
19	480.0	34,140	71	38,500	80
20	307.2	28,360	92	31,000	101
21	6,982.4	28,770	4	108,500	16
22	3,904.0	36,230	9	152,500	39
East of city limits,				48,500	
		574,950		1,000,000	

In order to obtain an estimate of the present density of population, and in order to make an estimate of the future density, the above table has been prepared.

The present population, the areas in acres, also the density, are given for each ward. The two last columns give the estimated population and its relative density when there are one million inhabitants. Such a population, in consultation with yourselves, it was thought proper to allow for when proportioning the capacity of the sewerage system.

It may be added that an increase of population beyond the assumed figure will not require an enlargement of the sewers, now recommended to you. The greater population will occupy additional territory and therefore require more sewers; perhaps, also, an additional intercepting sewer. This requirement has been given due consideration, and it will be practicable, in the future, to build other sewers, in order to relieve any surcharge of those already existing, and at the same time, form a proper part of the entire system. In other words, it will not be necessary to rebuild or cause

to be useless any essential and material part of the work now proposed.

To indicate the assumed distribution of the population, and thereby to make it convenient to ascertain the population on every area contributing to a given sewer, a population map was constructed by placing a red dot at what was assumed to be the centre of each five hundred of the prospective population. By counting the dots in each sewerage district, we determined the quantity of sewage to be expected therefrom.

It will be noticed that in the built-up parts of the city there is no very large difference in the density of population. We have assumed that this characteristic will generally be retained, although it is true that in the business centres of our large American cities the "day population" is increasing to very large numbers. We think that a suitable allowance in the capacity of the lateral sewers will provide for this fact.

E

WATER SUPPLY, SEWAGE AND GROUND-WATER.

The present population of the city is about 575,000. The greatest consumption of water recorded by the City Water Department is about 72,000,000 gallons per day. As the city water works supplies a small population in the Highlandtown and Canton District east of the city limits, the present consumption of water averages only about 120 gallons per head of the total population in the districts where city water pipes are laid. At this average rate the total consumption of water of one million inhabitants would be about 120,000,000 gallons per day.

The proposed low level system of sewers of the filtration project will collect sewage from an area that is practically identical with that covered by the proposed Low Service and Middle Service Districts, recommended in the Report to the Water Commissioners and recently adopted. From the data given in that report it is estimated that the maximum consumption of water in these two Districts will be about 74,650,000 gallons per day for a population of about 560,000, at the time when the city will have one million inhabitants. This gives an average consumption of about 133 gallons per head.

The proposed high level system of sewers for the filtration project

will collect the sewage from all the remainder of the city's area, which is practically identical with the area covered by the proposed High Service and Upper Service Districts, as rearranged in the report above mentioned. From the data given therein it is estimated that the maximum consumption of water in these two Districts will be about 46,000,000 gallons per day for a population of about 440,000 when the city has one million inhabitants. This gives an average consumption of about 105 gallons per head per day.

The low level system of the dilution project collects sewage from an area that is practically identical with the proposed Low Service District, and the high level system from an area which is practically identical with the proposed Middle, High and Upper Service Districts. Again, from the data given in the above mentioned report, there is an average daily consumption in the former of about 140 gallons per head and in the latter of about 112 gallons per head per day.

The proposed increase of pressure of water throughout the system will surely tend to increase the consumption, and in the absence of restrictive measures against wastefulness it cannot be expected to be kept within reasonable bounds.

Irrespective of the expense of furnishing an excessive amount of water to your population, it will be desirable in the future to adopt effective measures for the prevention of waste, because the water will have to be dealt with a second time, namely, as sewage. A larger consumption than necessary will not only increase the size required for all of the sewers and force mains, but the sewage will have to be pumped to a considerable height, and all of it subjected to a process of purification.

We have made a provision for 150 gallons per head of population per day to reach the intercepting and outfall sewers as sewage, and we are of the opinion that this amount is both reasonable and sufficient. An increase beyond the same would be due to waste, which should be and can be prevented. Or, it would be due to the use of water, perhaps for power and other similar purposes, which would not cause it to be fouled. Therefore it does not require to be discharged into sewers and delivered at the purification works, but can and should be discharged into the drains provided for the removal of rain-water.

The use of water is not uniform throughout the twenty-four hours of the day. We find its greatest use to be during the forenoon and its least use to be during the small hours of the night.

For District main and branch sewers the maximum flow may rise to double the average, on account of the hilly territory and rapid collection. For the intercepting and outfall sewers we have allowed a maximum flow equal to fifty per cent. greater than the average.

Sewage consists of the waste or refuse water from buildings after it has served the general purposes of cleansing, and been fouled by the discharges from bath-rooms, water-closets, urinals, kitchens, laundries, sculleries, stables, factories, etc.

Rain-water flowing off from streets with heavy traffic is sometimes as foul as domestic sewage. But as efficient street cleaning will prevent an objectionable result, we do not consider it necessary to treat it as being equally foul, nor as becoming objectionable when entering the drains, the rivers and the harbor.

When a water supply is liberal, the appearance of sewage is like dirty water. It consists of about 998 parts of water, about one part of organic matter, and perhaps one part of mineral matter. The organic matter contained in the sewage is that which by putrefaction causes the subsequent nuisance.

At first it has a very slight odor, resembling that of laundry water, on such days when much washing is done, and on other days it generally has the odor of an uncleaned kitchen sink.

In a new system of sewers, properly built and well cleaned, we have repeatedly detected these odors, as described, at the outfall. After sewers have been used for some time, and particularly where they are not carefully cleaned, a foul odor is detected, and it increases in proportion to the neglect in the care of the system. Where old sewers, that have been long in use and are improperly constructed, or where overflowing cesspools are connected with a new system, the odor at once becomes foul, because they contain much putrefying matter which readily affects the condition of the passing fresh sewage.

Although an effort should be made to prevent ground water or sub-soil water from entering the sewers, we have made an allowance for the infiltration of 100,000 gallons per day per square mile of territory. The ground water of the low districts of the city should be disposed of by other channels, as indicated below.

With the maximum flow of sewage and ground water, as thus estimated, we have assumed that the intercepting sewers should run half full, and the outfall sewer on Patapsco Neck two-thirds full. The force mains delivering the sewage at the filtration fields must of course run full at all times.

While we believe that 100,000 gallons of ground water per square mile per day is sufficient allowance throughout the greater part of the city, we do not think it is sufficient in the low parts of the city near the harbor. The reason for assuming a larger quantity in this locality is the fact that much of the ground water in the higher parts of the city will descend below the levels of the sewers and drains and reappear at the level of the intercepting sewers in the lower parts of the city. We have estimated that means should be provided at these sewers for removing ground water to the extent of 1,200 gallons per day per acre, or about 750,000 gallons per square mile.

F

RUN-OFF FROM STORMS.

In designing drainage works it is of greatest importance to ascertain the quantity of water per unit of surface, for the removal of which provision should be made.

Underestimating this quantity and thereby making the sewers, drains or other channels too small, would result in flooding streets and cellars, and damage to property. It must therefore be avoided. On the other hand, too great an allowance should not be made, as the sizes of the drains and other structures, and consequently their cost, would be unnecessarily increased. The problem requires that a proper medium be maintained between the two extremes.

The amount of rain-water for which provision should usually be made has not yet been satisfactorily determined, because it varies with a number of conditions, some of which can be expressed by a formula, while others must depend upon judgment, and because as yet an insufficient number of observations have been made on the subject to know the precise relationship of the factors.

We may say that the run-off varies with the amount of rainfall, and also with the slope, imperviousness, dryness, shape and extent of the area.

Observations are being made on the run-off in the City of Washington by the Engineer Commissioners of the District, and information, valuable also for Baltimore, will no doubt be there obtained in time. It will be sufficient for the present purpose to analyze some of the usual formulae that have been proposed, and, as they are fairly applicable to Baltimore, to apply them intelligently until better results are available.

The formulae discussed below are those of Hawksley, Adams, Burkli-Ziegler, McMath, and one deduced from diagrams prepared for the Department of Public Works of New York, in 1889.

They are as follows:

Let Q = Run-off in cubic feet per second.

r = Maximum rate of rainfall in inches per hour.

c = A coefficient dependent mainly on the character of the surface.

A = Drainage area in acres.

S = Average slope of area per 1,000 feet measured along the flow lines.

Then, according to :

Hawksley, $Q = c \sqrt[4]{r^3 A^3 S}$
for $r = 1$; $cr = 0.70$

Adams, $Q = c \sqrt{r} \cdot \sqrt[6]{A^5} \cdot \sqrt[12]{S}$
for $r = 1$; $cr = 0.57$

Burkli-Ziegler, $Q = cr \sqrt[4]{A^3 S}$
for $r = 2.75$; $c_1 r = 2.0625$ for paved and
built-up areas.
 $c_2 r = 1.705$ for average city
areas.
 $c_3 r = 0.8525$ for rural areas.

McMath (for St. Louis), $Q = cr \sqrt[5]{A^4 S}$
for $r = 2.75$; $cr = 2.0625$.

New York Diagrams, $Q = cr A^{.85} S^{.27}$
 $c_1 r = 1.64$ for completely
built-up areas.
 $c_2 r = 1.39$ for well built-up areas.
 $c_3 r = 1.02$ for suburban areas.

(a) *Maximum Rate of Rainfall.*

The most important factor is, of course, the greatest rate of rainfall. It is necessary to have exact observations not only concerning large storms, but also concerning those which have the greatest intensity.

The records of a number of excessive storms, which have occurred

during the past twenty-five years or more at several places in the State of Maryland, and also in the cities of Washington and Philadelphia, have been extracted from "The Weather Review" published by the Department of Agriculture (formerly by the Signal Service of the War Department), and are given in the Appendix.

Among these storms there are a number which were recorded by automatic gaugings and which for that reason are more useful in the present instance than the others. Such records have been plotted on the diagram contained on Plate N, the lesser storms being omitted as unnecessary. The ordinates represent the rate of rainfall in inches per hour, and the abscissas the duration of this rate in hours and minutes. The locations and dates of those storms which have exceptionally great rates and durations, are indicated outside of a dotted curve. The greatest storms have been designated specially, regarding place and date of occurrence.

From a study of these records it appears that the drains should be proportioned for a run-off from storms having a rate of 4 inches per hour.

In New York City a rainfall of one inch in 10 minutes or at the rate of six inches per hour, has occasionally been recorded, and this rate may be used for proportioning the drains from private premises and from short blocks.

The formulae above mentioned assume the run-off to vary with the rainfall, as follows:

All factors, excepting the run-off and rainfall, are assumed in this comparison to be constant.

Hawksley,	$Q = \text{constant} \cdot r^{.75}$	} Q varies directly with r .
Adams,	$Q = \text{constant} \cdot r^{.50}$	
Burkli-Ziegler,	$Q = \text{constant} \cdot r$	
McMath,	$Q = \text{constant} \cdot r$	
New York Diagrams,	$Q = \text{constant} \cdot r$	

There is hardly a question that, all other factors being equal, the run-off from such small areas as are considered for city drainage, should vary directly with the rainfall in all cases of heavy storms, and also for short periods if absorption and evaporation can be neglected. Therefore, as these assumptions can generally be made for city work, the three latter formulae which have a direct variation with the rainfall are preferred.

(b) *Slope.*

When the maximum rate of fall does not cease before the run-off from the entire area has reached its lowest point, then for this area the run-off will be independent of the slope. But when the maximum rate ceases before this takes place, the slope will have a decided influence upon the quantity of water accumulated.

The greater the slope of the surface, that is, the steeper the territory, the more rapidly will the water run off and accumulate along the lowest lines.

It is not practicable at this time to state how large the area must be before the variation of the slope should be considered. It depends upon the maximum rate of rainfall, upon the steepness of the area and upon other local conditions. For the present purpose the question will be neglected, as the information regarding it is still too indefinite.

Assuming, generally speaking, that the run-off increases with the slope, what is the ratio between these two quantities?

If all factors excepting the run-off and slope are assumed to be constant, then the above mentioned formulae exhibit the run-off to vary with the slope in the following ratios:

Hawksley,	$Q = \text{constant } S^{.25}$
Adams,	$Q = \text{constant } S^{.083}$
Burkli-Ziegler,	$Q = \text{constant } S^{.25}$
McMath,	$Q = \text{constant } S^{.20}$
New York Diagrams,	$Q = \text{constant } S^{.27}$

The exponent to the value S , exhibiting the ratio, does not show any great difference, excepting in the formula of Adams. The latter has the smallest exponent and the New York Diagram the largest; the latter, therefore, indicates a greater variation due to the slope than the other formulae.

(c) *Imperviousness and Dryness.*

These two characteristics of the surface are represented in the above formulae by a coefficient c , which must vary with the degree of imperviousness and dryness of the surface. Open ground, such as fields, parks and gardens, is comparatively pervious, while roofs and pavements are impervious. A wet soil will be less pervious to a sudden heavy rainfall than a dry one. Dry and hot street

and roof surfaces will cause more evaporation than wet and cool ones. But this variation is of no practical importance in the present case, as, by the time the maximum rate of rainfall occurs, all surfaces are thoroughly wet and cool.

It is assumed in the above formulae that c varies directly with the degree of imperviousness, that it is constant for each degree, and that therefore the run-off Q varies directly with c .

(d) *Shape of Area.*

None of the formulae mentioned take any account of the shape of the area, although it must necessarily affect the quantity of run-off. A violent and short rainfall upon a long and narrow area produces a smaller run-off at a given point, other things being equal, than upon a short and broad area. Still, for city drainage areas, which are comparatively small, this variation is not of material consequence, and has therefore not been considered. Owing to the lack of data, it is hardly worth while to consider it at all in your case.

(e) *Extent of Area.*

The larger the area, the greater is the total run-off. But, the larger the area, the smaller is the run-off per unit of area, as for instance per acre. This variation is important and demonstrates that a drain taking the water from a large area, say 100 acres, does not require to have ten times the capacity of one taking the water from only 10 acres.

Assuming all the factors, excepting the run-off and drainage area, as being constant, then the above formulae give the following values:

Hawksley,	$Q = \text{constant } A^{.75}$
Adams,	$Q = \text{constant } A^{.833}$
Burkli-Ziegler,	$Q = \text{constant } A^{.75}$
McMath,	$Q = \text{constant } A^{.80}$
New York Diagrams,	$Q = \text{constant } A^{.85}$

As regards the effect of the extent of the area upon the run-off, it will be seen that the coefficient does not indicate any great difference between these formulae.

(f) *Conclusion.*

All the above formulae have the form

$$Q = cr^o A^m S^n$$

From what was said above, the only formulae giving an exponential value for r other than unity are those of Hawksley and Adams, and it is as well to ignore such variation. Therefore the preferred formulae have the form

$$Q = cr A^m S^n$$

As they are practically derived independently of a knowledge of the exact maximum rainfall, we may substitute for cr the value of C , and therefore write

$$Q = C A^m S^n$$

In the Burkli-Ziegler formula we may therefore assume for the greatest storms the values:

$$C_1 = 2.06, \text{ for built-up areas.}$$

$$C_2 = 1.71, \text{ for average areas.}$$

$$C_3 = 0.85, \text{ for rural areas.}$$

McMath's formula for the City of St. Louis, gives the value

$$C = 2.06$$

On the New York Diagrams the values are:

$$C_1 = 1.64, \text{ for completely built-up territory.}$$

$$C_2 = 1.39, \text{ for well built-up territory.}$$

$$C_3 = 1.02, \text{ for suburban territory.}$$

Either of these formulae, if judiciously applied, will be useful in determining the proper sizes for drains in the City of Baltimore.

G

EXISTING SEWERS.

The City of Baltimore is, at present, without a system of modern sewers. The use of cesspools for the reception of excrementitious

matter is almost general. The human dejecta are now retained in them until periodically removed by excavation. On the sloping territory some of these accumulations are naturally on ground which is higher than that upon which other dwellings are located, and in porous ground there will naturally be a percolation of the liquids to lower territory where they may reappear near the surface. That they will be somewhat purified is beyond a doubt, and it is also certain that the purification will in some cases not be complete, and occasionally cause conditions which may be dangerous to health.

Nevertheless, the death rate of the City of Baltimore is not high. But it is higher than its topographical location justifies, and higher than in many other cities, which though much less favorably situated, have a better system of sewage collection and removal.

Waste water from kitchens, bath-rooms, etc., is generally turned out on the surface of the ground and runs away in the open street gutters, thence into drains and finally into the watercourses at points where the discharge of such foul liquids must become objectionable.

In a few instances, private sewers are said to discharge into some of the drains now acting as public sewers, and into open watercourses or directly into the harbor. In many instances, it is said that the cesspools have overflows into the drains.

Here and there some better means of sewage collection and removal may be in use, but the instances are few, and have therefore no bearing upon the design of a system of sewers.

It should be stated here that a clear distinction is to be made between sewers and drains. The former are channels which receive and carry away foul water or sewage from houses, and are always closed in. The latter may be open or covered, and are channels which receive and carry off rain-water, sub-soil water, or, in general, any water that is not foul or not sewage.

In Baltimore it was intended that the large drains, locally called sewers, should carry off only surface and sub-soil water. But in the absence of a sewerage system the polluted gutter water or sewage enters the drains. It was expected that at some future day this condition would be changed.

The drains have, therefore, been built in a manner which may be justified, if they are to be used for the removal of comparatively clean water. They are not built in a manner which will make them serviceable for the removal of foul water or sewage.

A few of these drains lately built were personally examined by one of us. They were found to have been built of good material, and the workmanship appeared excellent. So far as could be judged the sections were well constructed for strength and durability.

A number of the newer and older drains were examined as to their capacity, and it was found that they are sufficiently large to carry off the rain-water from the heaviest storms that may be liable to reach them.

A few of the older drains, such as that on Central Avenue, are quite inconsistent as to sizes and should be remodeled.

In the Appendix a table gives the results of a few calculations concerning the present size and capacity of the drains, and also of the capacities which will be necessary in the future. Some will, no doubt, need remodeling, according to the principles mentioned under Section R.

The water, as it flows out of the present drains, resembles sewage, although it may not contain as much organic waste matter as will be found in a modern system of sewerage. As the drains are not constructed to remove sewage rapidly and completely, there is much decomposition and foulness, and the sewage at some points is therefore now even a more obnoxious liquid than is generally found at the outfalls of properly designed sewers. It is discharged at the heads of bays where there is but very little circulation of water. The slight tidal rise and fall at Baltimore does not remove it properly, and allows it to accumulate and increase in foulness.

H

MODERN METHODS OF SEWAGE DISPOSAL.

The object of a modern system of sewerage is to remove as quickly as possible from inhabited territory the sewage discharged from the buildings. The removal should not only be rapid, in order to prevent decomposition before the sewage is disposed of, but it should also be thorough and not allow of deposits or accumulations in the sewers, which create foulness within them and cause the escaping air to pollute the atmosphere. A further object of modern sewerage is to dispose of the offensive liquids finally in such a manner that they will cause no nuisance and that they are converted into uninjurious and inoffensive liquids.

There is no need of stating to you that the only proper method of sewerage for a large city is the water carriage system, by which the waste matters from buildings, such as can be suspended or dissolved in running water, are carried away by it. No reference will therefore be made to other methods, some of which still have their advocates. No reference will be made to the use of earth closets. Though excellent for individual houses to which a sewer is not accessible, and excellent for the disposal of excrementitious matter alone, yet they cannot be considered a part of a sewerage system for a city, because they do not dispose of the large quantity of fouled waste water.

There are several methods according to which sewage can be safely and properly disposed of, namely, by a dilution in large bodies of water, by precipitating and separating from the sewage a large proportion of the organic matter, and by filtration of the sewage through porous soil. These methods will now be discussed more fully, together with their application to the City of Baltimore.

It should be added at this place that the object to be obtained is first and foremost a sanitary one, namely, the purification of the sewage. The question of cost, though important, is but secondary.

It may also be added, that the question of utilizing the manurial elements contained in the sewage must be decided upon the basis of cost. If the expense of extracting these elements is greater than the price at which they can be sold, it is preferable to waste them. The latter conclusion is the usual one. When sewage is purified by filtration on land this land can usually be devoted to the raising of crops. But experience has shown that the increased productiveness is due quite as much to the liberal irrigation with water as to any fertilization derived from the same. It is often necessary to use additional fertilizers to produce the desired crops. But the ill effect of droughts is entirely avoided and the farmer is more sure of his crops.

I

DILUTION.

To dispose of sewage by dilution means to discharge it into running water in a suitable proportion so that no putrefaction will take place, and that the oxygen contained in the water will gradually decompose the organic matter of the sewage and convert

it into harmless compounds. When sewage is thus diluted it gives no offense.

We have examples of this in the discharge of sewage into large streams, such as the Mississippi, Missouri, Ohio and Schuylkill rivers, which are all even used for drinking water. It must be understood, however, that the question in which we are here concerned does not refer to the discharge of sewage into a stream which is subsequently to be used for drinking purposes.

The question as to whether or not sewage may be properly discharged into a given river, is decided by the degree of nuisance that will be caused by the pollution. This nuisance is partly due to the unsightliness of sewage matter stranded along the shores or on any shoals that may exist during low water. It is mainly due to the offensive odors that arise from putrefaction. Putrefaction occurs when there is insufficient oxygen present in the water to allow the dead organic matter to be decomposed solely by oxidation, which is itself not an offensive process.

While it is therefore practicable to discharge some sewage into the running water of streams, there is a limit to the quantity when the excess of free oxygen contained in the water becomes insufficient to oxidize it. To obtain the best results by this dilution method of sewage disposal, it is necessary to have the sewage matter dissolved or well comminuted so that it can be thoroughly exposed to the action of the oxygen.

Therefore, no constant relation can exist between a certain quantity of sewage and the amount of flowing water that will render it innocuous. Where the velocity of the stream is lessened and there is consequently a chance for deposit, sewage will require a greater dilution than if the flow is rapid and continuous.

As a measure of the amount of permissible pollution, the sewage should be indicated, not so much by its actual quantity, as by the population from which it comes, and by the quantity of manufacturing refuse which it contains. The amount of waste organic matter is more constant with reference to a given number of persons than to the amount of the sewage coming from them. The latter depends almost entirely upon the liberality with which the public water supply is used and subsequently discharged as sewage.

It has been found that the sewage from one thousand persons can be satisfactorily diluted in non-tidal streams by a flow of water varying from two to seven cubic feet per second, according to the different conditions of the stream. Under the conditions

found in Baltimore, where there is a very sluggish flow of upland water, and also a slight tidal current, it would not be safe to allow less than a minimum flow of three cubic feet per second to render the sewage of one thousand persons inoffensive.

When sewage is discharged into a tidal stream, it must be realized that the fluctuation of the tide causes not only a downward, but also an upward current. Therefore sewage discharged into it will oscillate and be carried away much more slowly than the apparent outflowing water of ebb-tide. The question of dilution in tidal streams is therefore almost entirely one of dilution by the upland water which enters the stream and gradually pushes out into the ocean.

The oscillation of a large quantity of tidal water has, besides, the effect of a more thorough dispersion by the greater velocity and mass of the water, also the effect, which is sometimes beneficial, of causing a deposit of the heavier matter, which will thus free the water from carrying it in suspension and more highly polluting it. The deposited matter is then sometimes carried away or dispersed during freshets.

If the tidal stream though wide, is also short, there is another beneficial effect in the circumstance that a large proportion of the sewage is carried out into the larger body of water where the tidal stream discharges, and with the incoming tide does not always return into the stream. It is therefore permanently removed from it.

In connection with this method of disposal it should not be forgotten that a discharge into salt water causes a less rapid oxidation than a discharge into fresh water; and also that the value of fish and other aquatic animals in disposing of sewage is very slight, and should not be counted on.

The effect of sewage discharged upon oyster beds, wherever sufficient inquiry was made, has been found deleterious. Evidence has been obtained, for instance, in New Haven, that the discharge of sewage near oyster beds, and the subsequent eating of the oysters, caused typhoid fever. Similar evidence has been obtained elsewhere.

In order to show the probable effect of discharging sewage into the Patapsco River at different points under the least favorable conditions, the necessary calculations were made. These conditions occur when the dry weather flow enters the river from its drainage area, and therefore contributes the least amount of water to dilute the sewage.

The best available information regarding the least dry weather flow of the streams about Baltimore is as follows:

From the United States Census of 1880 we find that the dry weather flow of the Patapsco River above Ellicott City and above Relay is about 0.22 cubic feet per square mile per second.

From information furnished by the Water Department of the City of Baltimore we find that the dry weather flow of Gwynn's Falls is 0.41 cubic feet per square mile per second, and that of Jones' Falls is 0.44 cubic feet per square mile per second.

From the United States Census we learn that the minimum flow of Rock Creek at Washington, D. C., is 0.114 cubic feet per square mile per second.

In our calculations we have assumed that the minimum flow from the creeks and from the general territory within the City of Baltimore, including the Patapsco River, is 0.2 cubic feet per square mile per second.

The entire drainage area of the river above a line drawn from North Point to Rock Point, is 556 square miles. The minimum flow of upland water at the mouth of this river would therefore be about 111 cubic feet per second.

If we assume that the sewage of 1,000 persons can be properly diluted in a large body of water by a minimum flow of 3 cubic feet per second, then the Patapsco River could, without becoming offensive, receive the sewage of about 37,000 persons.

It will be evident, therefore, that no system of sewerage that is recommended for your city should contemplate the discharge of all of its sewage into this river. It will be necessary to reserve its limited diluting power to counteract the effects due partly to the refuse discharged into the river and its branches from the ships and wharves, partly to the refuse which is brought down and discharged into the river by the drains during storms, when the surface of the city is washed clean of much organic deposit, and partly also to a small amount of sewage which, at least at present, it will be found preferable to discharge directly into the river from Ferry Point and near Fort McHenry.

Calculations were also made to show the displacement of the tidal prism by the upland minimum flow. Owing to the width of the river below the city, it is found that the gradual movement toward Chesapeake Bay is very slight, and that, if sewage were discharged into the river, it would be removed very slowly, and therefore cause objectionable conditions.

A disposal of the sewage of Baltimore by dilution, therefore, would mean nothing less than the building of a sewer to near North Point and of discharging its contents into the current of Chesapeake Bay. No point nearer the city and no smaller body of water, such as Back River, would prevent dissatisfaction.

North Point was suggested already in 1881 for this purpose by Mr. Charles H. Latrobe, C. E., in his "Report on a System of Sewerage for the City of Baltimore." This outfall was placed in about fourteen feet of water.

The channel in the bay is near the Eastern Shore, and no place having more than eighteen feet of water at mean low tide is found within two and a half miles of the Point.

It is, therefore, necessary to discharge the sewage into the comparatively shallow water of the bay and into a tidal current. A calculation with reference to the flow of upland water which would pass down Chesapeake Bay opposite North Point during extreme dry weather, based partly on observations and partly on deductions, is about 6,800 cubic feet per second. The ordinary minimum discharge is about 20,000 cubic feet per second.

Therefore, could the sewage of Baltimore be discharged into the current of the waters of Chesapeake Bay, it is safe to assume from what was said above that at the lowest figure applied to non-tidal streams, the sewage of about two and a quarter million people might thus be disposed of at the most unfavorable time.

The effect upon the oyster beds, so far as we are able to judge at the present time, is problematic. It is true that there is evidence showing the danger of having oyster beds near the sewage outfall. But, in case ill effects are positively demonstrated, and in case there were no other method of disposing of the sewage of so large and important a city as Baltimore, then it would be necessary to abandon as many of the oyster beds as would be subject to pollution.

In order to deliver the sewage at North Point it would be necessary to build an outfall sewer all the way from the city. Mr. Allen made surveys and profiles of several lines, as directed by us, from which after a careful study, the best one was selected.

Assuming a starting point on the Shell Road at Twenty-fifth street, the line extends to General's Point, there crosses Bear Creek by means of an inverted siphon, described below, and continues in an easterly and then southeasterly direction until it reaches a gate house at the shore, also described below, and thence is continued with a submerged outlet into the current of the bay.

A settling basin should be constructed at the upper end of the outfall sewer, to collect the sand and other solid matter which will settle. It is an underground chamber into which the outfall sewer discharges, and has two channels for the sewage, so that one channel can be in use while the other is shut off. Each channel should have a gate at each end, and one in the division wall between the two channels, for drawing off the sewage left in the channel between the gates when they are closed. A sump is placed in the bottom of each channel for collecting the sand.

A house is erected over this chamber with provisions for thoroughly lighting and ventilating the channels. A traveling crane and hoisting apparatus for cleaning out the sumps should be placed in this building, and the necessary tracks provided, on which small cars can receive the sand and deposit it at a dumping place.

The inverted siphon under Bear Creek has an underground chamber on the west shore from which two five foot nine inch brick conduits extend underneath the bottom of the creek to two vertical wells rising to an underground chamber on the east shore of the creek, out of which chamber the outfall sewer extends eastwardly to the outfall. In the chamber at the west shore a gate is placed in front of each siphon opening, and in the chamber at the east shore there are stop planks to allow either siphon to be shut off and pumped out in case of a break.

Both of these siphons should be built at once, but they are large enough to take the total amount of sewage estimated to flow in the outfall sewer when the city has one million inhabitants. In order that the smaller amount of sewage, which will be collected at first, may flow through the siphon at a velocity sufficient to keep sediment from depositing, only one of them should be used for present service. Then, in case of a break the sewage could flow through the other conduit. In order to provide for the remote contingency of a break in both conduits, an overflow pipe opens out of the side wall of the chamber on the west shore, through which the sewage can be discharged into the creek. A house should be erected over each of these underground chambers, having arrangements for thoroughly lighting and ventilating them, and for operating the large conduit gates and setting stop planks.

A settling-basin should be built at the bottom of the sewer, just west of the upper chamber, so as to keep whatever solid matter may have passed the main settling-basin from getting into the siphon.

A gate house is located on the shore of Chesapeake Bay, from which two outfall pipes extend into it about two and a half miles. As only one of these lines of pipes need be built for present service, two overflow conduits have been provided and extend to the shore of the bay, so as to discharge the sewage in case of a break or stoppage in the outfall pipes.

Gates are provided for these conduits, and manholes for their examination or repair. A retaining wall protects the gate house and overflow conduits from the sea. A house should be built over the gate chamber with provisions for lighting and ventilating it. The gates of the overflow conduits are operated from the floor of this house, and arrangements exist for raising and lowering each gate.

The route of the main collecting and intercepting sewers through the city is shown in detail upon the plan and profile which accompany this report.

The territory lying below the line of the gravity main intercepting sewer is served by low level interceptors, practically skirting the edge of the branches of the river and the harbor, one or two blocks from it, and collecting the sewage to a low point near the intersection of Lombard street and Jones' Falls. Here, a pumping station would be located, where the sewage could be lifted and discharged through a force main into the main intercepting sewer at Broadway and Lombard street.

The location of this pumping station was selected with reference to concentrating the sewage to the best advantage, and with due regard to economy both in constructing and operating the system.

The station, as shown on the plan, has been designed to contain a pumping plant of sufficient capacity to raise the sewage from the low level system to the high level interceptor, at the maximum rate of flow, when the city has one million people.

It has been estimated that the total amount of sewage from the low level system would amount to 32,250,000 gallons per 24 hours from about 215,000 persons, and assuming that one-half of this sewage is delivered in eight hours, the maximum flow into the pump well is at the rate of 48,375,000 gallons per 24 hours.

To pump this amount to the high level interceptor requires two 25-million gallon pumps, and a boiler capacity of about 500 horsepower. To have sufficient reserve power, this station is designed to contain three 25-million gallon pumps and three 250 horse-power boilers.

It is presumed that all of the low level intercepting sewers would be constructed in a few years, and that the construction of the District sewers and branches is extended over a much longer period. Therefore, it is estimated that the total amount of sewage for which present pumps should provide, is about 10,500,000 gallons per day, coming from about 70,000 persons. Assuming that one-half of this amount runs off in eight hours, the maximum delivery of sewage would be at the rate of 15,750,000 gallons per 24 hours. To pump this quantity to the high level interceptor requires one 25-million gallon pump and one 250 horse-power boiler. The station should therefore be provided at once with two 25-million gallon pumps and two 250 horse-power boilers.

The sewage from the low level system is brought to the pumping station through a 3 foot 6 inch main sewer from the south and a 2 foot 4 inch sewer from the north in Front street, and a 5 foot 6 inch sewer in Water street.

The two sewers first mentioned join near the pumping station, and the sewage from both is brought to the pump well through a 4 foot 6 inch sewer. The sewage from the 5 foot 8 inch sewer is brought under Jones' Falls to the pump well in a 4 foot 6 inch siphon tunnel. These two 4 foot 6 inch sewers are brought to a gate and cage chamber. After passing the gates the sewage flows through a screen cage, which collects the larger solid particles of the sewage. There are two such cages for each of the two main sewers, one in front of the other, so that when one is being cleaned, the other screens the sewage. A hoisting apparatus raises and lowers them. It is operated by an engine located at the end of the boiler room, and is so arranged that it can be operated by hand, if there should be an accident to the engine.

The screenings can be thrown into a car and taken to the boilers and burned.

From the cage chamber the sewage discharges into a screen well, from which conduits lead to the suction pipes of the pumps, in front of which are inclined composition-metal screens preventing the finer particles from entering the suction pipes. These are kept free and clean by raking from a platform in the well provided for that purpose. The screenings are also to be burned.

The screen well is accessible by a flight of steps and is lighted from overhead and thoroughly ventilated through a large brick conduit extending to a flue in the smoke-stack.

The pumps discharge into a 48 inch force main, which would extend out Lombard street to the high level interceptor.

The coal house would be large enough for storing about 100 tons of coal, and teams could be driven up the inclined driveway from the street in front of the pumping station, and the coal delivered through chutes in the side windows of the coal house.

The smoke-stack for this station would be about 100 feet high and five feet interior diameter of core. It is so arranged that an economizer could be placed in the smoke flue leading from the boilers to the stack.

In locating the intercepting sewers above mentioned, many difficulties were met, such as the crossing of Jones' Falls, Gwynn's Falls, the B. & O. Railroad Tunnel and numerous large drains, and solutions studied out so as to make the lines practicable and comparatively inexpensive.

The elevation of the water in the well at the pumping station was fixed at about 18 feet below mean low water, from which it was necessary to lift the sewage fifty-two feet, in order to discharge it into the high level interceptor and outfall sewer. The territory from which the sewage would require pumping, was estimated at about 3,550 acres, having a present population of about 183,000 persons, and an estimated future population of about 288,000 persons.

The sewage of the different parts of the city would be delivered by main sewers, suitably located to collect the sewage economically from each natural sewerage district.

J

PRECIPITATION.

Another method of disposing of sewage is to clarify it by the addition of certain chemicals, to let the clear water enter a stream and to put the settlings on land. When milk of lime, salts of iron or aluminum are added to the sewage, much of the organic matter contained therein is coagulated and gradually settles to the bottom. The supernatant liquid is thus cleared and relieved of a large portion of this organic matter. Experience shows that about one-half of the organic matter originally contained in the sewage can thus be precipitated.

To allow the sewage to deposit its suspended matter without the addition of chemicals is not advantageous. It is true that

some of the heavier particles will fall to the bottom when the velocity of the sewage is reduced, or entirely ceases, but the process is slow and imperfect. It does not remove a sufficient quantity of the offensive matter to justify the expense of such a plant.

The precipitated sewage matter, or "sludge," must be artificially removed from the settling tanks and separately disposed of.

The treatment by precipitation consists in allowing the sewage to enter large tanks after it has received the proper quantity of chemicals, and to allow it either to rest, or to pass very slowly through the tanks, so that the suspended matter can settle to the bottom before the water leaves them. It is allowed to flow out over a weir as a thin sheet of water. There must be enough of these tanks to enable the sewage to pass through at a sufficiently slow rate, and to allow of a sufficient number to be out of use, while the sludge is being removed from them.

The disposal of the sludge is the most difficult part of the process of sewage precipitation. As it is in a semi-liquid form, the best method of dealing with it, under all but extraordinary conditions, is to pump it into so-called sludge presses, which remove the water and transform the sludge into solid cakes which can readily be disposed of. They can be used either for filling in land, or, where the expense of hauling is not too great, they have been profitably used to fertilize land, or they have been burned.

The best example of sewage precipitation in this country, and perhaps in the world, is at Worcester, Mass., with which works you are, no doubt, more or less familiar. The sludge has there been disposed of by pumping it upon land and letting the sun dry it. At present, however, arrangements are being made to erect presses and to transform it into cakes, as described above.

The advantage of a sewage precipitation plant, so far as Baltimore is concerned, is the circumstance that while the outfall sewer for a dilution project would have to be built at once with its full capacity, a precipitation plant need be built at first only of a size to accommodate the early flow of sewage, and then be gradually extended as the amount of sewage increased. Another advantage of such a plant would be its temporary use along the line of the discharge mains to the proposed filtration fields, and thus temporarily save the cost of preparing the latter and of pumping the sewage to so great a height.

The disadvantage of such a plant lies in the fact that its operation is somewhat expensive. It has been found in Worcester, where

the works are managed with exceptional skill, that the annual cost of treatment, exclusive of laboratory expenses and sludge disposal, has been nearly 30 cents per head of population.

Considering this cost to be the same in Baltimore, and adding a proper amount for the pressing and disposal of the sludge, we have estimated, for such treatment in your city, an annual expense of thirty-five cents per head of population. If we assume a future population of one million inhabitants, the annual cost of precipitation, including sludge disposal, would then be \$350,000.

When the clarified sewage is discharged into a stream, it must also be diluted in order to prevent subsequent offensive decomposition. But the dilution need not, of course, be so great as in the case of raw sewage, containing suspended organic matter which is much slower in yielding to oxidation.

It is uncertain how much of this sewage effluent may be safely discharged at the mouth of Colgate Creek or into the Patapsco River.

As the process removes only about one-half of the organic matter there is, under favorable conditions, still a cause left for offensive decomposition. In fact, in the absence of sufficient oxygen the dissolved matter yields even more rapidly to putrefaction than the suspended matter. But once exposed to oxygen it will also more rapidly be converted into inoffensive compounds. If, instead of 3 cubic feet per second, as above assumed in the case of raw sewage, we were to allow but one-tenth of this quantity, or 0.3 cubic feet per second of fresh water, to dilute the effluent sewage from precipitation tanks per 1,000 persons, the minimum flow of the Patapsco River, estimated above at 111 cubic feet per second, would be capable of receiving such effluent water from only 370,000 persons. To discharge the effluent from one million people during the late summer months, might therefore possibly become objectionable, particularly as no allowance has above been made for the effect of the pollution of the harbor by the shipping and by storm water discharge.

A precipitation project, as a permanent solution of the problem of sewage disposal for the city, should therefore require a discharge of the effluent water into Chesapeake Bay.

A convenient location for the precipitation works is on a tract of land lying easterly of the city, and on the southerly side of Fifth avenue, near the head of Colgate Creek, as shown on the map. Nearly 80 per centum of the entire sewage of the city can be

brought to the works by gravity, while the balance will have to be raised about 52 feet by pumping.

The works have been designed to treat, for the present, an average of 50,000,000 gallons of sewage per 24 hours, or for a population of about 330,000 persons. There are 48 tanks required, 10 of which are 92.4 by 325 feet, 18 are 50 by 172 feet, and 20 are 50 by 150 feet; in all of them the sewage will average 6 feet in depth. The combined capacity of the tanks is 27,229,500 gallons, or a little more than 50 per cent. of the estimated present flow. They have been so designed that a part, or the whole of them, can be built at once; also, that additions can be made from time to time, as the flow of sewage increases. They will cover an area of 680 by 1,100 feet, or about 17.13 acres, including the channels.

The method of treatment suggested for the sewage, and for which the works were planned, requires the use of lime and sulphate of alumina as coagulants, and filter presses for treating the sludge.

Buildings have been planned to accommodate the necessary machinery to apply this method. They consist of a screen house, engine and boiler house, chimney and a sludge-press house.

The screen house, with a screen chamber and rack, is built over the main outfall sewer, so that all foreign substances may be detained and as often as necessary removed from the screen by rakes. These screenings are taken to the boilers and burned.

The boiler and engine house is 50 by 80 feet, with two floors. The boiler room is at one end of the lower floor, and the other end contains the engines, chemical mixers and electric motors. On the second floor are the chemical store room, laboratory and offices for the superintendent.

The sludge-press building, on the opposite side of the sewage channel, is 48 by 102 feet, single story, and contains the sludge pump and presses. It is devoted exclusively to this part of the work. A reservoir is placed under the ground at one end of this building, where the sludge is collected from the tanks previous to pumping it into the presses.

It is probable that a portion of the power needed for driving the chemical mixers and dynamos used for lighting, may be derived from the fall of the effluent as it is discharged into the creek. There is an available fall of about 10 feet, and assuming a daily flow of 50,000,000 gallons, there would be 87 gross horse-power, but as the discharge is extremely variable, it is not safe to estimate more than one-half, or about 40 horse-power. The balance required must be

supplied by steam, and steam power is necessary for operating the various pumps.

Estimates of the amount of sludge that will be produced are based upon the assumption that for every 1,000 people 54 cubic feet of sludge may be expected, and that for the assumed population for present purposes 18,000 cubic feet per day will have to be taken care of. Twenty-two sludge presses and four sludge pumps are required for this amount. Ample capacity for taking care of the sludge should be provided, for upon its prompt removal depends much of the efficiency of such a plant.

For mixing the chemicals eight mixers are estimated. They are designed to run by independent electric motors; this method being much more simple than the older method of shafting and belts.

Several vats for slacking the lime are also provided in the building.

There are two 50 horse-power boilers, one engine and an electric dynamo; the latter is required both for transmitting power and for lighting.

Should the effluent water be used for power, a wheel-house and dynamo are needed near its outlet. The power could be brought through the engine room by wires and then distributed as needed.

The method of operating the works is as follows:

The sewage, after passing through the screen house, enters the mixing channel, where it receives the milk of lime, and a few feet further a solution of sulphate of alumina. After a thorough mixing by a mechanical device, or by flowing over and around obstructions placed in the channel, it then enters the gate house, where it can be diverted into either one of the various channels, and by means of gates, is first discharged into the larger or roughing tanks, where the bulk of the solids is deposited. From these tanks the sewage flows over a weir, at the farther end of the tank, into the influent channel. Skimming boards are placed in front of the weirs, to prevent solids from flowing over into it.

From the influent channel the sewage passes through gates into the smaller or finishing tanks, where the finer particles are deposited. From these tanks the clarified sewage flows over a weir into the effluent channel and thence to the creek.

The frequency with which the tanks require cleaning will depend entirely upon the amount and foulness of the sewage. Ordinarily the larger tanks require cleaning about three times a week, or every

other day, while the smaller tanks are cleaned once or twice a week, as may be required. For this purpose the effluent water in the tanks is drawn off by means of skimming pipes placed at the farther end, opposite the inlet, and leading into the effluent pipes under the channels. It is discharged into the creek at a lower elevation than that discharged from the effluent channel.

The sludge, or what remains after drawing off the upper clear liquid, is then drawn back through special channels into the main sludge pipes, leading into the reservoir located at the end of the press house. From the reservoir the sludge is raised by pumps and forced into the presses, forming "sludge cakes."

Experience shows that about 90 per cent. of the sludge is water and the foul liquid which is separated from it by the process of pressing needs to be re-treated. To accomplish this, the presses are placed on a level above the mixing channel, so that the liquid coming from the presses can run back into it.

Water pipes connected with hydrants and conveniently placed, should be laid around the tanks so that they can be thoroughly washed after the sludge has been drawn out. The water for this purpose can be taken from the effluent channel and pumped directly into the pipes as needed, or a storage tank can be built at a sufficient height to give the required pressure.

The amount of chemicals required depends largely upon the character of the sewage, but it is generally considered that 8,000 grains of lime and 2,000 grains of sulphate of alumina are ample to properly clarify 1,000 gallons of average American sewage.

If the works are carefully managed there need be no nuisance about them, excepting at the tanks holding the sewage, and for which reason it is desirable to locate them in a neighborhood that is not populated.

The route of the main collecting and intercepting sewers is the same as for the dilution project previously described, and shown in detail upon the plan prepared for it.

If a precipitation plant is used for temporarily treating the sewage which is later to be purified by filtration, it may be located on the south shore of the Patapsco River, east of Brooklyn, or it might even be built on unoccupied land near Ferry Point. In either case, the works need not be built as permanently as recommended for the location at Colgate Creek. The tanks could be built of creosoted timber instead of masonry, and the temporary sewers leading thereto could be made of the same material. The buildings

might also be built of wood. The estimates of cost have assumed timber to be used for these several structures.

K

FILTRATION.

Sewage can be disposed of also by filtration. If it is allowed to run through coarse material, such as broken stone, it will deposit a large amount of its suspended matter upon the stones and, dependent upon the quantity of sewage so discharged and the length of time in which it travels through this material, the sewage will emerge more or less purified. The stones, however, gradually become coated and require replacing.

For small amounts of sewage, such a system of filtration, which is little better than a straining, will sometimes answer. It will not answer for treating the sewage of a large population, under conditions which prevail in Baltimore. The expense of properly preparing such a bed of stone, and the attention which must be given to it in its management, and to its occasional replacing, altogether make such a system of disposal not only less perfect, but also more expensive than other methods, which are more extensively used and which will now be described.

When the sewage is turned upon a porous soil, pure sand being the best, it percolates through the same more or less rapidly, owing to the coarseness of the sand and to the head of sewage resting upon it. The first result of this percolation is a straining out of the coarser particles. As the water passes down, the subsequent result is to expose it to the action of bacteria, which, directly or indirectly, accomplishes the thorough oxidation of the sewage matter, so that, under favorable conditions, the escaping water at the lowest point of the filter will be freed from the objectionable quantity of organic matter and from the myriads of bacteria which are found in the raw sewage.

The Massachusetts State Board of Health, in its admirable work on the Purification of Water and Sewage, has demonstrated the favorable conditions for this purifying action, and, by a very extensive series of experiments with different kinds of soils and sands, has given the profession a means of judging what can be accomplished, without doubt, by filtering sewage of a known character through a material of a known character.

It was formerly thought that the best method of disposing of sewage on land was to have it absorbed by vegetation. This view caused many of the English sewage farms to be originally laid out solely for the purpose of crop raising, and it was held, for instance in Croydon, that the water of the sewage should either be evaporated from the surface or taken up by the crops, but not allowed to percolate through the soil. Therefore sub-drainage was not advocated.

While this process gave satisfaction when properly operated, it required a very large area of land per thousand persons. This large area was not always obtainable. In order to use a smaller area it was found necessary to sub-drain the land, and thus to free it of the water which had percolated into the ground. This water was found to be comparatively pure, and, in some instances, quite pure.

It was then proposed in England by Dr. Frankland to purify sewage by means of intermittent filtration, by which method the purification was accomplished, not necessarily through the aid of crops, but by the passage through porous soil. Intermittency was necessary, according to Dr. Frankland, so that the pores, which at one time are filled with sewage, are alternately filled with air, to supply the oxygen which is necessary to finally accomplish the purification. Intermittent filtration was first practically applied in England, by Mr. Bailey Denton, and its success was assured nearly twenty years ago.

The recent experiments of the Massachusetts State Board of Health related to intermittent filtration, as it was found that a continuous filtration of sewage through sand was absolutely void of satisfactory results, the sand then acting merely as a strainer and the sewage escaping with its dissolved organic matter not removed.

We are to-day in a position to state, not only that sewage can be thoroughly purified by filtration through porous soil, in percolating slowly and intermittently through it, but also that the fields can be arranged so that crops may be successfully raised, while at the same time the sewage is being purified.

The application of this method is, of course, only available where the necessary area of land of suitable quality can be had. A search on the eastern side of the Patapsco River to discover such land proved unavailing. On the western side, in Anne Arundel county, as has already been stated under Section C, there is an abundance

of land which is well suited for the purification of the sewage of the City of Baltimore. It is shown on the U. S. Geological Survey Map which is appended, Plate M.

The distance to this territory is not greater than the distance to a sewage outfall at North Point into Chesapeake Bay. In fact, there is a large area of suitable land somewhat nearer. Some of the territory is at present covered with timber and some of it is under cultivation.

With reference to disposing of sewage on land, it should be stated that no nuisance need arise from the same. When delivered from a well-managed sewerage system it is supposed to be comparatively fresh, and should have but a slight odor. But, even if it has an odor when delivered upon the fields, it is found that after it has been distributed and has filtered away there is practically but little, if any, offense.

From the samples of soil taken from the proposed filtration areas at Glen Burnie, it will be safe to estimate, according to the locality, for a disposal of from 10,000 to 25,000 gallons of sewage per acre per day, without stripping off the top soil. If it is all taken off and only sand remains to receive the sewage, this area will probably purify from 30,000 to 50,000 gallons per acre per day. The territory north of Furnace Creek is on the average not as good as the area south of it. It would be well to assume the lower of the above figures for it.

Assuming that 500 acres are available north of the Creek, we can therefore dispose upon it 15,000,000 or 5,000,000 gallons daily, according to whether the top soil is removed or not.

Assuming that south of Furnace Creek there are 1,000 acres available, we could on the average dispose of 40,000,000, or 15,000,000 gallons of sewage daily, according to whether the top soil is taken off or not.

There are large areas of timber land, some orchards and some marsh land on this territory, some of which can be made available if necessary, as beneath a surface layer of from 6 to 12 inches in depth coarse sandy soil is found.

The Elvaton filtration area comprises the territory of Marley Neck and Tick Neck and other lands down to Magothy River. It is better adapted for sewage filtration, because the sand is almost free from loam. We think it will purify about 25,000 gallons of sewage per day without stripping, and perhaps as much as 50,000 with stripping.

There are about 8,000 acres available on this territory. After a thorough preparation and removal of the surface layers of soil, the Elvaton area may therefore take as much as 350,000,000 gallons of sewage daily.

From the above it will be seen that there is within a reasonable distance of Baltimore a large territory available for the purification of sewage. In fact, there may be as many as 10,000 acres obtainable above the Magothy River, which altogether would answer for purifying the sewage of more than two millions of people. Both the cities of Paris and Berlin are obliged to carry some of their sewage further off before proper territory for purification is reached.

The Glen Burnie area is shown on one of the maps, Plate H, together with a general outline of the way in which it can be adapted for sewage filtration.

In order to get the best results, the ground must be stripped and freed from the top layer of soil. A proper system of distributing the sewage should be laid out so as to utilize the ground at all times to the best advantage.

The ground of each bed, which should contain about one acre, should be leveled, and generally provided with ridges and furrows so that the sewage may flow over it uniformly and not accumulate at some low point which would overcharge a portion, while another portion receives an insufficient quantity. The ground must also be thoroughly under-drained, because the water, after percolating through the sand, must be rapidly removed in order to permit of a proper intermittent aeration, and thereby secure the maximum duty.

Before the sewage is allowed to spread over the fields, it may be advisable, and it is sometimes necessary, to screen it so that there will be less deposit upon the fields. Occasionally it is even advisable to allow much of the heavier matter to deposit in tanks before the sewage is turned upon the fields. A larger quantity can then be filtered per acre of ground. But this expedient will probably not be necessary in this case, as there is no scarcity of land.

Regarding the raising of crops and operating a sewage farm, it is best to start tentatively and to ascertain the best methods of cultivation and management for the local conditions existing in your neighborhood. Some crops do better than others. Some will use up more sewage than others. Some are more profitable and find a more ready market than others.

Vegetables should be grown upon ridges and protected from a direct contact with sewage, just as it is undesirable to bring them in direct contact with manure.

Ensilage is meeting with success in Europe, and if you find it practicable and economical to raise large crops of grass, it would be well to experiment with regard to preserving the grass in the manner which is profitable in England.

Well-managed sewage farms do not create a nuisance. Residences of well-to-do people are found in the neighborhood of such farms in England, and in a few instances also on the continent of Europe. In Berlin there are several homes for convalescents from hospitals in the midst of the sewage farms, and some other similar institutions are intended to be placed there. The death rate on large English sewage farms, according to Baldwin Latham, in 1880, was but three per thousand. On the Paris and Berlin farms it is similarly low. In the City of Baltimore it is now over twenty per thousand.

Fish breed freely in the effluent water from the Paris and Berlin and the best English sewage farms.

The manner in which the sewage of the city may be collected and delivered at the disposal areas is shown on the plans. The Glen Burnie area is about six miles from Ferry Point and the Elvaton area is about ten miles from the same. The elevation at which the sewage can be distributed on the nearer territory is 55 feet and on the farther territory 80 feet above datum.

It is desirable, of course, to deliver as much sewage as possible upon these areas by gravity. We find that about one-third of the assumed population, namely, about 365,000 persons, will eventually reside upon territory which is sufficiently high to deliver its sewage upon the Glen Burnie area by gravity. It is not practicable to deliver any of the city's sewage at Elvaton by gravity.

At Glen Burnie there are about 1,400 acres upon which sewage may be purified, about 200 acres of which lie west of the discharge mains. Therefore, if we estimate an acre to purify 40,000 gallons per day, the Glen Burnie territory is just about sufficient to receive the sewage that can eventually be delivered by gravity. The sewage of the remainder of the population will have to be pumped and eventually delivered on the higher Elvaton area.

Until the population of the city discharging its sewage into the system exceeds about 350,000 persons, all of it can be delivered to Glen Burnie, which will postpone the preparation of the higher

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area for a number of years, and also the laying of the separate discharge mains leading to it.

We therefore advise that the Glen Burnie area be prepared first, and that it be used for all sewage delivered until its full capacity has been reached, and thereafter that the Elvaton area be prepared.

The method of collecting and delivering the sewage upon the filtration areas will be described further on.

L

COMPARISON.

In making a comparison between the above-mentioned three possible methods of disposing of the sewage of the City of Baltimore, we should consider the preference both for future and for present conditions.

The methods of disposal are the discharge of crude sewage into the deep water of Chesapeake Bay, the discharge of clarified sewage into the Patapsco River and eventually into Chesapeake Bay near the shore, and the purification of sewage by filtration in Anne Arundel county.

The difference in cost between these methods is in our opinion not sufficient to decide the question of preference. We believe that it should be decided upon other grounds.

When we consider that there is a practical way of quickly and thoroughly purifying the sewage of Baltimore without creating a nuisance, and at the same time utilizing it for irrigating lands which to-day have but a small value for agriculture; when we consider that a discharge of crude sewage into Chesapeake Bay does not at once effectually dispose of it, but allows it to oscillate with the tides in the navigable waters and over present oyster beds before it is thoroughly dispersed; finally, when we consider that the effluent from a precipitation plant is but clarified and not purified sewage, and that there is insufficient flow in the Patapsco River to properly dilute it when the city has grown to about double its present size; we have no hesitation whatever in recommending the purification of the sewage upon the sandy territory in Anne Arundel county, as the best solution of the problem for all time.

We consider the city, in fact, to be unusually fortunate in possessing sufficient suitable territory so near its limits. There is hardly another large city in the country which is equally favored in this

respect. No experiment will be made in thus disposing of the sewage, as experience has been obtained in thus dealing with it for nearly half a century. From Berlin and Paris, which have the largest sewage filtration fields, down to the many smaller cities in England, and also in several cities and towns of our own country, the process has been tried and developed so that it is quite safe to predict the results obtainable under given conditions, and to prevent any possible failure. To reach a successful result it is merely necessary to apply existing and obtainable knowledge to the preparation of the filtration fields and to their subsequent operation.

We feel certain that the purification of sewage by land filtration will be found a far more satisfactory disposal in your case, than either the partial purification by chemical means, or the crude disposal into the Bay. Filtration is likely to settle the question for all time, just as it has so been settled in many other cities, while with the less perfect purification, future trouble is apt to arise in your case, pointing to the possibility of eventually changing the method and incurring further expense.

While we are of the opinion that a disposal by filtration is the best method for your city to adopt in the future, we believe it is also best at first. The crude disposal system requires at once the construction of a large outfall sewer to North Point. It would have to be built of a capacity answering for a distant future, which capacity would therefore not be required for a long time. The precipitation plant could be built with a small capacity at first, but there remain the other facts that the sewage is merely clarified and not purified, and that no use can be made of the effluent water. The filtration system at once purifies the sewage and utilizes it for irrigation. It need be laid out at present only sufficiently extensive for the quantity of sewage which it is to receive. Its area can be increased gradually, which thus avoids a large investment of money at the outset. A further reduction in the first outlay could be made by a temporary chemical treatment along the western shore of the Patapsco River. The expense of the discharge mains to the filtration fields and the cost of preparing the latter, would be saved until the precipitation system had reached its capacity.

After having presented our conclusions, which advocate a final disposal of the sewage by filtration in Anne Arundel county, it is now necessary to inquire into the methods to be adopted for collecting the sewage from the city and delivering it at the proposed fields.

M

METHODS OF COLLECTION.

There are in use several methods by which sewage can be collected in a city and taken out of the same. In every case there are, of course, pipes or sewers which conduct the sewage from the houses to the street, and then along the streets to a pumping station or to an outfall. As the rain-water must usually be carried off in a similar manner, it has been found economical in large cities to carry the sewage and rain-water together in the same channels. This is done with the so-called *combined* system.

There are cases, however, where it is not economical to build sewers to carry off both these waters. In smaller cities it is customary to allow the rain-water to run off on the surface of the streets, so far as practicable, as such surface removal usually does not interfere with traffic, nor is it otherwise objectionable, and it saves the expense of large sewers. In such cases, the sewage alone is taken away in pipes, and not mingled with the rain-water. This is usually called the *separate* system.

There are still other conditions where this system is preferable. Where it is necessary, for instance, to pump the sewage, the admission of rain-water necessitates a much larger plant for pumping, much of which is in use only during storms. In almost all cases it is possible to allow rain-water to run off by gravity into natural watercourses, and therefore to avoid pumping. To combine it with sewage when the latter requires to be lifted, is usually not economical.

Again, where it is necessary to give the sewage some treatment, *i. e.*, to purify it either by the chemical or the land treatment, it will be evident that if rain-water is admitted to the sewers, a much larger quantity of water must be dealt with, and therefore the expense of treatment is materially increased.

When a combined system is used, it is however always understood that, when sewage is either pumped or treated, all of the rain-water is not subjected to this handling. There are overflows provided in the sewers which allow any excessive storms to discharge their water into natural watercourses. The water of slight rains only is allowed to remain with the sewage, and it is usually proper to allow this quantity of water to be about double the greatest flow of sewage.

The admission of rain-water to this extent has frequently been advocated, because the first wash from the streets contains a good deal of waste organic matter. Where a pollution of the water-course, due to such washing of the street surfaces, is objectionable, it is proper to have the rain-water disposed of in such a manner.

In some cities a provision for rain-water removal has been made and drains have been built before the question of sewage disposal became urgent and demanded a solution. If such drains are fairly good and of sufficient capacity to take care of the rain-water, then, when the removal also of foul water is required, it is usually found best, for economical reasons, to adopt the separate system.

N

SEPARATE SYSTEM.

The City of Baltimore being provided with drains to a large extent and at a great cost, and most of such drains being fairly well built and efficient for their purpose, is one of those cities in which the separate or double system is preferable.

It may be added that some years ago it was urged that a separate system was preferable in all cities, from a sanitary point of view, and that it should be introduced in all large cities, even if it required a complete double system, one for sewage alone, and the other for rainfall alone. The arguments then made have, however, not been substantiated by facts, because it was found that the cities which had a combined system, well built and carefully managed, generally had a lower death rate than before such systems were introduced, and that other cities, adopting a separate system of sewerage had no lower death rate, and, in at least one instance, even a higher rate than in cities where the other system was in use.

There is no reason, either theoretical or practical, why a separate system should be preferable from a sanitary point of view, and, therefore, the question of preference between the two systems should always be decided on the basis of cost. In Europe we find the separate system in use only in a few English cities. In America it is used more frequently, and, therefore, the experience gained with it here has been greater. There are no large cities where it is as yet used, however. The City of New Orleans has adopted it, and the system is under construction, but not yet in use.

The conditions existing in Baltimore are peculiar, and different from most other cities as regards the sewerage question, and therefore it is necessary to examine it carefully and independently.

The existence of an expensive system of drains for rain-water removal, the necessity for treating the sewage, as has already been stated, and also the necessity for pumping most of the sewage of the city, argue for the adoption of the separate system more strongly than in any other large city in the United States which has not yet been provided with a modern system of sewers.

It may be mentioned here that Mr. Charles H. Latrobe, C. E., in his able report upon the sewerage question in the City of Baltimore in 1881, recommended the separate system.

There is a certain flexibility in such a system, as regards the admission of rain-water. In England, where it is used in a number of smaller cities, it has been urged that a portion of the rain-water should be admitted for the purpose of flushing the pipes. It is there customary to allow the rain-water falling upon the back roof of the house, and sometimes also that falling upon the back yard, to enter the separate sewers. The advantage of this custom lies in the fact that the increased flow through the sewers gives an admirable flush. The water entering at all their heads simultaneously, causes a flush, not only of the laterals, but also of the main sewers.

In England the rainfalls are not as intense as they are in this country, and a provision to admit their water as described, therefore, does not require such a large additional capacity as would be necessary in Baltimore. In the United States, it has been practiced in many cases, to admit only roof water for the above purposes, and it has been found to be an advantage whenever the arrangements have been proper.

The difficulties to be met are in the limitation of the amount of water which thus enters the sewers from each house, and also in the limitation regarding the number of houses allowed to discharge their roof water into the sewers. It is evident that the advantage to the system is obtained only from the water admitted near the heads, and that the roof water lower down in the system should be excluded. As such a discrimination is not always practicable, it is also customary to accomplish the same end by flush tanks, usually placed at the heads of the lateral sewers, and discharged either automatically or by hand.

The advantage to be expected from flushing the upper ends of the sewers is the removal of deposits, due to the fact that the

sewage flow is not only slight, but also intermittent, and therefore permits such deposits to form. Lower down in the system, after receiving the sewage from many laterals, there is a constant flow, and if the sewer is designed to cause a sufficient velocity and a proper sectional area, deposits are not usual, and are due only to an extraordinary occurrence, which makes it necessary to remove the deposit or obstruction by special means.

It remains now to describe the principal features of the sewerage system as recommended to you; to follow it with a description of a drainage system for the city, and to conclude with an estimate of cost.

O

PRINCIPAL SEWERS AND DISTRICTS.

The methods of disposal recommended, being a filtration upon land in Anne Arundel county, it is necessary to collect the sewage and deliver it to this land in the most economical manner.

As already mentioned, the elevation of part of the area that can be used, is sufficiently low, so that some of the sewage can be delivered there by gravity. It is, therefore, economical to divide the city by a high level intercepting sewer, collecting all the sewage which can flow by gravity to this area.

As a large portion of the territory over which the sewage is taken to the disposal area lies below the hydraulic gradient, it must be carried in pipes under pressure.

The remaining part of the city, lying below this gradient must have its sewage collected by a low level interceptor, situated as near to the shore line of the river as possible. Owing to difficulties of construction and expense, there will be some small areas along the water front that cannot discharge into the interceptor without special pumping, but may discharge into the river. As the amount of sewage is small, it cannot be objectionable in the harbor, when compared with the pollution caused by the shipping interests.

After some study, it was found best to locate the lowest point at which the sewage of the low level interceptor is collected near the intersection of Leadenhall and Stockholm streets. This point is convenient for collecting the sewage, and for receiving coal, and is therefore a suitable location for a pumping station, where the sewage can be forced into the discharge mains leading to the filtration fields.

As the amount of sewage to be collected in the high level interceptor will, for a long time, be comparatively small, and as a large portion of the population resides at an elevation which is much above that through which the low level interceptor is carried, it has appeared that a mid-level or intermediate interceptor might be an economical feature of the system. It would prevent a large portion of the sewage from flowing down to the lowest point to be again raised by pumps.

A general location for such an intermediate interceptor was made, and also a calculation to determine whether there would be economy in its adoption. The result showed that the mid-level interceptor project did not save expense.

An advantage would be its temporary use for collecting the sewage from the high level territory, thus for a while saving the building of the high level interceptor. This advantage, however, was not material.

A disadvantage, on the other hand, was found in a greater complication of the works at the pumping station, due to a separate set of engines, and in the necessity of increasing the initial outlay for the system, while without it it is only necessary to pay annually a sum for pumping the sewage to the additional height.

For present needs it is unquestionably cheaper to pump the smaller quantity of sewage obtained from the higher territory, than to build the mid-level interceptor at a cost which is intended to provide for the population of the future. Pumping machinery is continually being improved, reducing the cost of pumping so that it is rather probable than otherwise that the economy now apparent for pumping the sewage will become still greater.

It should be added here that a mid-level interceptor may form a means, in the distant future, of increasing the capacity of the sewerage system of the city upon the area it now occupies, in case such increase should ever be necessary. It is impossible to foresee the precise development of a city, and if, in many years, the low level interceptor should be found too small to do the work which with present foresight may be expected from it, then, without interfering in any way with the use of works that are now built, it would be more practicable to add a mid-level interceptor than at the present time. We therefore do not recommend its construction.

The entire area of the city has been divided into separate and distinct sewerage districts, some of which have their sewage discharged into the upper and others into the lower interceptor. The

boundaries of these districts are shown upon the plan, Plate G. In each one the sewage is generally collected by district main sewers which eventually discharge into the respective interceptors.

These districts are usually identical with the natural drainage areas. Towards the northeast there is one, the Herring Run district, which naturally does not drain into the Patapsco River, and from which the sewage must be intercepted in order to be united with the rest of the sewage of the city.

The boundaries of the districts as marked can, of course, only be approximate, and will have to be adjusted later when the details of the system are elaborated. The alignment of the intercepting and main district sewers, as marked upon the maps, is likewise only approximate and will require further adjustment.

The route of the high level interceptors is as follows:

From the intersection of Eutaw and Franklin streets, where the interceptor discharges into gravity discharge mains which lead to the filtration fields, the eastern interceptor extends in a northerly direction to the intersection of Mount Royal avenue and McMechen street. It then crosses the valley of Jones' Falls by means of a pair of inverted siphons. These siphons cross in a tunnel sufficiently below the level of Jones' Falls so as to be in rock. They consist of iron pipes carried down the shaft, through the tunnel and up again in a shaft at 21st street (Plate J). It is better to carry the sewage across in special pipes than in a brick-lined tunnel itself. In the latter case there would be too small a velocity at first, owing to the large sectional area, and if reduced in area the necessary velocity in the future would consume too much head. The tunnel may be used also for other purposes. From the siphon the interceptor continues on 21st street to Hargrove alley, thence on North avenue and Barclay street to 20th street. It crosses the Jenkins Run valley by another pair of inverted siphons and then takes a southerly route on Ensor street to Hoffman and Preston streets. At Caroline street it again turns north and, as shown on the plan, reaches North avenue at Broadway, near which it terminates. It can receive the sewage from practically all of the territory lying between it and the southwestern boundary of the Herring Run district.

There is a small area in the Jenkins Run valley, north of North avenue, from which the sewage cannot be taken into the high level interceptor. This sewage will have to be carried south of North avenue and discharged into a low district sewer along Jones' Falls which discharges into the low level interceptor.

The sewer has been given a gradient so as to secure a mean velocity of three feet per second, east of Jones' Falls, and a velocity of four feet per second west of Jones' Falls.

It may be possible, when working up the details of the system, to slightly lower this eastern high level interceptor and thereby decrease the length of the siphons across Jenkins Run.

The western high level interceptor, beginning at the intersection of Eutaw street and Druid Hill avenue, extends, as shown on the plan, with many changes of direction which are necessitated by the topography and the layout of the streets, to the intersection of Pratt street and Fulton avenue. It is located on Pratt street for several blocks and at Pulaski street extends in a northwesterly direction into the valley of Gwynn's Run, which it ascends and terminates where its gradient strikes the level of the run.

This interceptor will receive all the sewage north of it and from both sides of Gwynn's Run valley north of the crossing of the Baltimore and Potomac Railroad.

As it is uncertain whether it will be desirable in the future to discharge the sewers, built in Gwynn's Falls valley, into the high level or into the low level interceptor, or into neither, both of them are made large enough to receive the sewage from such territory. The increase of size is inconsiderable.

The district mains of the upper system should naturally be carried down through the lowest part of the area. In many of them the streets are not yet laid out, so that no attempt was made to suggest the lines upon the plan.

As Druid Hill Park extends to the western side of Jones' Falls valley, and as between it and the crossing of the high level interceptor practically no sewage will have to be disposed of, it is deemed sufficient to place a main district sewer only on the eastern side of Jones' Falls. At Woodberry a branch can be carried across the Falls to a district which drains towards it.

There is a large quarry below the mouth of Stony Run and also other features which require a detailed study to determine the exact line along which this district sewer can be carried to the high level interceptor. If unexpected difficulties should arise, it will be necessary to at least temporarily discharge it into the low level system. There are no streets available upon which to place this sewer, and its location will therefore largely be a matter of procuring a right of way. It will be necessary to cross Stony Run with an inverted siphon.

The route of the low level interceptors is as follows:

From the pumping station at Stockholm and Leadenhall streets the eastern low level sewer extends on Leadenhall to Montgomery and thence to Charles street. It follows Charles street northerly to Balderston street and thence takes an easterly course on different streets, as shown upon the plan, to Jones' Falls, which it crosses by inverted siphons. It then takes the most available course to reach the intersection of Aliceanna street and Boston street, along which it skirts the Northwest Branch to Clinton street, the first street east of the city line. On Boston street it crosses under the Harford Run Intercepting Drain by means of inverted siphons.

From Clinton street this low level interceptor can be carried, as shown upon the plan, to Eighth street, thence northerly so as to cross the valley of Gorsuch Creek at Bank street. From this street it is practicable to continue the interceptor northerly with a fairly direct line so as to intercept the sewage from the Herring Run district. From Bank street it is also practicable to extend the low level interceptor so as to collect a large portion of sewage naturally draining into the valleys of both Gorsuch and Colgate Creeks as likewise shown upon the plan.

The area lying below the territory thus intercepted, and which at present lies outside of the city, in Canton, can in the future have its sewage conducted to a special pumping station situated at Gorsuch Creek, and pumped into the above-mentioned low level interceptor. When computing the size an allowance has been made for this contingency.

It is too early to suggest any definite project for collecting the sewage from the northeastern corner of the city which naturally drains into Herring Run. The territory is as yet undeveloped. Should it require sewerage, there are two possible ways of treating this area. The separate system should, of course, be adopted, because the sewage should be discharged into the general system of the city, while the storm water should flow into Herring Run.

It is practicable to collect the sewage of this area and to pump it from the lowest point into the high level interceptor on North avenue. It is also practicable to collect it at a low point and discharge it by a gravity sewer into the low level interceptor. The latter solution is indicated on the plans. From the fact that the territory has not yet been improved, we are obliged to limit our suggestions to these alternate and general solutions of the problem.

Owing to the uncertainty of how it will be found best to treat this

area, we have made allowance for sufficient capacity to receive its sewage, both in the eastern high level and low level interceptors.

The western low level interceptor begins at the pumping station, extends out Stockholm to Russell street, and thence out Russell to Putnam street. At this point it branches. One branch extends southerly, crosses Gwynn's Falls and intercepts the sewage from the territory lying south of it, which though not within the city limits to-day, may be eventually annexed and require facilities for sewage disposal. The other branch extends northwesterly on the best available line to the mouth of Gwynn's Run. It can then be continued to the valley of Gwynn's Falls, as indicated upon the plan.

The Bush street drain which crosses the line of this interceptor will be crossed so that no inverted siphons are required.

Regarding the territory west of Gwynn's Falls, we are at present able to make only some general suggestions. It is much broken up by valleys and is not yet regularly laid out with streets. When this section of the city needs sewerage, it is practicable to adopt either of three general plans.

It is possible to collect most of the sewage of this territory by means of inverted siphons carried across the valleys of both Gwynn's Falls and Gwynn's Run, on or near the line of Baltimore street, and to discharge it into the high level interceptor. It is also possible, and it may be less expensive, to collect the sewage and to carry it down the valley of Gwynn's Falls and discharge it into the low level interceptor at Russell street.

Inasmuch as we are unable to decide which of these two propositions may be found most expedient when it is necessary to sewer the territory west of Gwynn's Falls, we have allowed an increase in the capacity for both the western high level and low level interceptors for this purpose.

There is a third possible way of sewerage for this section. When it becomes well built up and when the territory lying south is no doubt also being improved, it is practicable to build an intercepting sewer from Irvington direct to the proposed Glen Burnie filtration area. This sewer will then serve the territory of the present settlements of Claremont and Mt. Winans.

We have not estimated the cost of the western low level sewer further than to the far end of Russell street, as it is somewhat uncertain as to how the line should be placed at such a time when this sewer may be constructed. We have, however, shown a possible extension by a dotted line.

Likewise, owing to the uncertainty regarding the exact location, we have estimated the cost of the eastern low level interceptor up to the city line at Clinton street. By a dotted line, however, we have shown a possible way of extending it into territory which, in the future, should be sewered by it.

Locust Point is provided with main sewers as follows:

An interceptor starts at Charles and York streets, extends easterly on the latter, and skirts the harbor as far as the intersection of Jackson and Clement streets where it terminates.

Starting at the pumping station another intercepting and main sewer extends southerly on Leadenhall to Barney street, thence on Race to Winder street, thence through a rather deep cut easterly to Allen street. It crosses the peninsula on Allen street to Clement street and thence follows the latter to the intersection of Garrett avenue, where both the sewer and the present built-up part of the district terminate.

It is also practicable to extend this sewer southerly as far as Jephson street and there to cross the eastern part of the peninsula. It is also practicable, instead of placing the main sewer on Clement street, to build one on Wells street and another on Marriott street.

Neither of these lines is low enough to take the sewage from Fort McHenry or Ferry Point. It is considered that this territory which is excluded, may not require sewerage for many years. But whenever it is necessary it will be practicable to discharge the sewers directly into both branches of the river, by carrying them out to the heads of piers or through submerged pipes.

It is possible, by placing the interceptors on Locust Point at a lower elevation, to sewer the entire area as far as Fort McHenry. The cost of lowering the system, however, is much increased, both for construction, and also from the fact that all of the sewage, even that from the high territory of the Point, will at once have to be lifted to a greater height. The area which is now left out is small. It comprises, besides the Fort, but a small area not at present built upon. From what has been said about the capacity of the river to receive sewage during dry weather and under the least favorable circumstances, without causing trouble, we believe that this small quantity can eventually be discharged into it without harmful results.

Should such discharge not be deemed desirable, it is also practicable to discharge into the above-described main sewers or interceptors, by collecting the sewage at convenient points and there

lifting it into them by automatic pumps, operating either by electricity or compressed air.

Between the two lines just mentioned, we give the preference to that which is more direct, because by saving the grade it reaches a greater distance and can collect the sewage from as far east as Garrett avenue, which is not practicable by the other line. The expense may be somewhat greater on account of the deeper excavation on Winder and on Clement streets, but this extra cost should not stand in the way of building a system which will effectively drain the largest possible area. The limit of the area is marked upon the plan, provided the street grades are favorably established.

The approximate location of the proposed upper district mains is indicated upon the plan. It will be noticed that a large main extends along the eastern boundary of Patterson Park. If found preferable, it can as well be located within the Park. District mains extend northerly from the interceptor on each side of Jones' Falls. Along a large part of the distance there is no street and the sewer will have to be carried along the railroad and a special right of way will have to be obtained therefor. In the low ground of the southwestern part of the city it will be well to place the main sewers more frequently so as to give the laterals sufficient fall. In order to collect the sewage from south of Winder street it will be preferable to build only a few district mains, as shown, into which the laterals discharge, rather than to carry these laterals on every street directly into the Winder street main.

On territory where streets are not yet laid out, it is advisable to make a careful study both of the sewerage and drainage requirements of such territory, and, if possible, to have the streets laid out in a manner which may not only serve the property, but also reduce the expense both of the sewerage and drainage of such territory. By considering the lay-out of property, with reference to these eventual requirements, it is often found that the total cost of improvement is much reduced.

P

PUMPING STATION AND DISCHARGE MAINS.

The pumping station has been provisionally located at the intersection of Leadenhall and Stockholm streets. The site should be selected not only with reference to collecting the sewage to the best

advantage, but also with reference to economy, in the purchase price of the land, in the construction of the work and in operating the system.

The station has been designed to contain a pumping plant of sufficient capacity to raise all the sewage collected from the low level system, and to deliver it to the filtration fields at the maximum rate of flow in the intercepting sewers, at a time when the population of the city contributing sewage has reached one million persons, and also to contain a small plant for pumping the ground water, delivered by the sub-drains of the low territory, into the Patapsco River.

It has been estimated that the future total amount of sewage of the low level system will amount to 95,250,000 gallons per 24 hours, coming from 635,000 persons; and it has been assumed that half of the sewage will be delivered at the pumps in 8 hours, or at the rate of 142,875,000 gallons in 24 hours. In addition, a small allowance has been made for ground water, which may find its way into the sewerage system, to the extent of 1,500,000 gallons in 24 hours. The total quantity to be pumped to the filtration fields will be 96,750,000 gallons in 24 hours, at a maximum rate of 6,015,417 gallons per hour, or 144,370,000 gallons per 24 hours.

The elevation of the invert of the sewers at the pump wells is assumed at -13.75 . The elevations to which the sewage must be lifted are $+81$ for the Glen Burnie pipes and $+119$ for the Elvaton pipes. The actual lift, when the sewers run half full, will therefore be 90 feet to Glen Burnie and 128 feet to Elvaton. As all pumping in the future will be confined to the sewage delivered at the Elvaton fields, the pumps should be proportioned for the greater lift.

The length of the gravity mains from Franklin street to Glen Burnie is about 55,050 feet, the length from the pumping station being about 37,900 feet. The length of the force mains to Elvaton is 57,000 feet.

To lift the above-mentioned quantities the station must eventually provide five 30,000,000 gallon pumps and a boiler plant of 4,100 horse-power.

The ground water collected at the station will be suitable for condensing the steam from the engines, and may be used for that purpose. But occasions might arise which necessitate its discharge into the Patapsco River. It would then have to be pumped against a head of 22 feet at the rate of 3,000,000 gallons per 24 hours, requiring one 3,000,000 gallon pump.

As there should be reserve pumps and boilers for the sewage and also for the ground water, the station has been planned to contain eventually six 30,000,000 gallon pumps, two 3,000,000 gallon pumps and ten 500 horse-power boilers.

It is presumed that all the low level intercepting sewers will be built within a few years, and that the building of the district sewers and branches will be extended over a much longer period. Therefore it has been estimated that in the low level system a present provision should be made for the sewage of only 260,000 people. The amount of sewage from this population, together with the ground water, gives a maximum rate of delivery at the pumping station of about 60,000,000 gallons per 24 hours.

To deliver this amount to the Glen Burnie filtration fields requires only two 30,000,000 gallon pumps and a boiler plant of 1,275 horse-power. Adding a reserve pump, then the station should at once be provided with three 30,000,000 gallon pumps for sewage, and with two 3,000,000 gallon pumps for ground water, altogether supplied by four 500 horse-power boilers.

The sewage of the low level system is brought to the pumping station through a 9 foot 6 inch main sewer extending northerly in Leadenhall street and a 4 foot 10 inch main sewer extending southerly in Leadenhall street, and a 6 foot 2 inch main sewer extending westerly in Stockholm street.

The two sewers last mentioned are connected at the corner of Leadenhall and Stockholm streets, and continue to the pumping station as an 8 foot 2 inch sewer. This and the 9 foot 6 inch sewer are brought together to a gate and cage chamber, where gates provide for shutting off the flow of sewage in either one or both of these large mains, in case of an accident to the machinery at the station. After passing through the gates the sewage is discharged into a well, across which four steel cages are set, with screens made of steel rods, for collecting the larger solid particles of the sewage. A hoisting apparatus, operated by an engine and located in a room adjoining the chamber, is set above these cages, to raise and lower them, when they become so filled with the solid matter as to impede the flow of sewage. The apparatus is so arranged that it can be operated by hand, should any accident occur to the hoisting engine. The screen-cages are hooked to a hoisting bar balanced by counter-weights, so that either one or all of the cages can be raised at once.

Steel screen gates are set in front of each cage and closed so as

to screen the sewage while the cage is being cleaned. They are hinged to the screen-cage guide posts, and so constructed that they can be operated from the floor of the house. The screenings can be thrown into a car running on a track from the cage house to the boilers and be burned.

From the cage chamber the sewage discharges into a screen well (a large underground chamber), out of which conduits lead to the suction pipes of the pump. There are six of these conduits grouped in pairs. In front of each group is an inclined screen-rack of composition metal, to prevent the finer particles in the sewage from entering the suction pipes. These racks are kept free and clean by raking from a platform in the well provided for the purpose. The screenings are placed in a receptacle, carried to a shaft which opens into a room adjoining the boiler house, raised in it to the upper floor, dumped into a car and taken to the boilers and burned. Access to this screen-well is provided by a flight of steps. It is lighted from overhead and thoroughly ventilated through a large brick conduit extending from near the top of the well to a flue in the chimney.

The conduits leading from the screen-well to the suction pipe are lower than the bottom of the well, so as to insure a sufficient depth of sewage for supplying the pumps at times of minimum flow.

At the head of each conduit a gate is placed to control the flow, and also to shut off the conduit from the screen well, in case of an accident to the pump. These gates are operated from the yard at the side of the engine house, and can be readily reached through the side door in the engine room.

The large sewage pumps discharge into a 48 inch main laid along the side of the engine house, and from which four 48 inch force mains extend to the discharge mains in Hanover street. Only two of these, however, will be needed for present service. The gates in the 48 inch main in the engine house are arranged so that additional pumps can be connected with it in the future, without interfering with the running of the other pumps, and also in such a manner that the remaining two lines of 48 inch mains can be laid and put into service at any time.

The condensers for the large pumps are set in the basement of the engine room, which are lighted from the basement court area in the rear of the engine house. The condenser pumps may be arranged so as to take water from the sub-drain well, or they can take the condensing water through a special pipe from the Patapsco River.

The several sub-drains, laid in the side walls of the intercepting sewers, are brought together at a well underneath the small pump room. A gate is placed at the head of this well, so that it can be entirely shut off from the drains. The well is lighted from the pump room floor.

If the ground water is not used for condensing purposes, it can be pumped from this well into the storm drain now laid in Stockholm street.

The boiler house is so arranged that additional boilers can be set up and put into service at any time. A small car track is provided for bringing coal to the boilers and for carrying away ashes.

The coal house at the end of the boiler house is intended to be large enough for storing about 200 tons of coal. Teams can be driven up the inclined roadway and the coal dumped through manholes in the roof; or, a spur-track can be laid around the pumping station, and the coal delivered directly from the cars into the coal house through chutes placed in the windows.

The chimney is about 250 feet high and the interior diameter of its core is $11\frac{1}{2}$ feet. It is so arranged that an economizer can be placed in the smoke flue, leading from the boilers to the chimney.

The station is equipped with an office for the chief engineer and has also a bathroom and a coat-room.

A traveling crane should be placed in the pump room for convenience in handling the machinery during erection and for making repairs at any time.

It should be stated that a sewage pumping station need not cause any nuisance in the neighborhood. The sewage is brought into the station under ground by the sewers, and the screens, pump wells and other receptacles are all under cover. The screenings are destroyed by burning, and the sewers, wells and chambers, as well as the buildings themselves, are thoroughly ventilated. Large sewage pumping stations exist within the cities of London and Berlin and give no offense whatever. Those in Boston are outside of the city, but there is no odor noticeable in their vicinity.

The sewage collected by the high level system at Eutaw and Franklin streets, eventually from 365,000 persons, has been estimated at 54,750,000 gallons in twenty-four hours, and the maximum rate of flow at 82,125,000 gallons per twenty-four hours. A small addition for ground water brings this rate to about 83,000,000 gallons.

The discharge mains, which carry the sewage to the filtration fields at Glen Burnie by gravity, will be two pipes 60 inches in diameter, with a maximum velocity of about 3.3 feet per second. As the total quantity of both sewage and ground water is estimated at 55,625,000 gallons in twenty-four hours, the mean average velocity will be slightly less than 3 feet per second.

The route selected for these gravity mains, starting at Franklin street, is through Eutaw, Henrietta, Charles, Moale and Byrd streets to near the Ferry Bridge, crossing the river nearly parallel with the bridge. The route then takes a straight course, almost due south, to a tunnel through the ridge, thence continues in the same direction to near Cabin Creek, where it turns slightly to the west, following nearly parallel with the Annapolis turnpike to Glen Burnie.

These two gravity mains have a hydraulic gradient of .00068, when flowing at a velocity of 3 feet per second, and .0008 when discharging the assumed maximum quantity of sewage and ground water.

As it will be several years before the amount of sewage from the high level system reaches the quantity that these two mains can carry, only one main should be laid at first, from Franklin to Ostend street, and two mains from there to the Glen Burnie filtration fields, ending one of them at about the center of the fields. The latter is to be temporarily used for the discharge of the sewage pumped from the low level system, and the former for discharging the high level sewage by gravity.

As the quantity of sewage increases, additional mains can be added from time to time. But they will have to be built to Elvaton, as the area at Glen Burnie cannot properly purify more sewage than can be delivered by the two mains laid at first.

To discharge the sewage from the low level system by pumping, when there are one million people in the city, requires three 60 inch mains laid to the Elvaton filtration fields.

These mains will have an hydraulic gradient of .0011, causing an average velocity of 3 feet per second, but at times of a maximum discharge the velocity will be about 3.8 feet per second. The route chosen for them, starting at the pumping station, is, to and along Hanover street to Cromwell, Marshall and Dorsey streets, thence to Ferry Point, and crossing the river parallel to the mains previously laid. As the hydraulic gradient has a higher elevation than the mains to Glen Burnie, this line can be farther east and go partly around the hill, which makes the necessary tunnel shorter.

Two tunnels are therefore required south of the Patapsco River. One containing the two mains which discharge at Glen Burnie is about 8,000 feet long, and of sufficient size to permit of access to them at any time. The other tunnel contains three mains discharging at Elvaton. It can be higher and therefore shorter than the other, and is but 3,400 feet long.

In crossing the river the discharge mains are estimated to be encased in concrete, as shown by a section on the accompanying plans, Plate I. A branch pipe and gate should be provided at or near the river, to allow the mains to discharge into it at any time, should an accident occur to them.

As the velocity in the gravity mains for the first few years will not reach the average, it will be necessary to flush them occasionally by accelerating the speed of the pumps and drawing the necessary sewage from the low level system, for which arrangements should be made. For flushing the upper portion of the gravity mains, north of the pumping station, a branch connects them with the main interceptor in Leadenhall street, so that its contents may at any time be discharged into the low level system with a highly increased velocity. If practicable, the grade should be such that these mains can be completely emptied.

Careful investigations should be made regarding the best material for the discharge mains to insure durability and economy. The estimates of cost have been made on the assumption that steel plates are used in the construction and that the pipes are made in the most approved manner, with butt joints and counter-sunk rivet-heads. In calculating the size Kutter's formula was used, with coefficient of roughness $n = .015$.

Q

ELEMENTS OF DESIGN.

a. Velocity of Sewage.

The question of velocity is very important, because if it is too slight, sewage matter will not be carried off but will be deposited, and if it is too great, a gradual destruction of the material of which the sewers are built will take place.

In order to make sewers self-cleansing as much as possible and to prevent deposit and foulness, the *least* velocity of the sewage

should at no time fall below 20 inches per second. When sewers are first put into operation, comparatively few houses are connected with them, and therefore the quantity of sewage will be comparatively small. At such times, however, the velocity should be not less than 20 inches per second. This remark is of importance only with reference perhaps to the upper end of the proposed intercepting sewers and to the branch or lateral sewers in comparatively level territory. At the upper end of the interceptors the difficulty, if expected, may be somewhat overcome by adopting an egg-shape rather than a circular section, as mentioned below.

The hilly nature of most of the city will generally secure a good velocity in both main and branch sewers.

We have found it practicable to assume a mean velocity of four feet per second for nearly all of the high level and for the eastern and western low level interceptors. This velocity not only secures their comparative cleanness, but it also allows their size to be reduced. This improved condition, and the economy resulting from the reduction of size, we consider to balance the cost of an increased depth of excavation and of the additional height of pumping made necessary.

We found it impracticable to assume so good a velocity for the interceptors and mains collecting the sewage from Locust Point. It would have required either leaving out some important territory or an increased lift at the pumping station, which, under the conditions, was not economical. We therefore assumed a mean velocity of three feet per second.

Similar conditions made it advisable to reduce also to three feet per second the mean velocity in the eastern high level interceptor above Jones' Falls. And it was found economical to assume this same velocity for both the force mains extending from the pumping station, and for the discharge mains extending from the high level system to the filtration fields. A velocity of four feet per second in the latter case would necessitate a material reduction of the area sewered by the high level system.

It is generally desirable to increase the velocity as the sewage approaches a pumping station or an outfall. Such gradual increase is a good preventive of deposit, but it is not always practicable. In the City of Baltimore, where the collecting interceptors must necessarily have a light grade, the sewage in them will have less velocity than in the district mains and laterals which feed them. Consequently there will be more deposit in the interceptors than

if the case were reversed. Ample arrangements for flushing them therefore become necessary.

The *greatest* velocity which should be allowed in a sewer was found, after much experience in England, to be about six feet per second; a greater velocity causes a gradual wear, even if the hardest materials are employed. This limit is confined to a continuous flow of sewage and not to the combined sewers where much greater mean velocities are occasionally permissible.

When the gradients of the streets are so steep that a sewer, laid parallel with the surface, would cause more than a six foot velocity, it is then proper that the grade of the sewer should be broken and vertical drops built to break also the velocity. Unless very hard and durable material can be employed in the construction of steep sewers, it may often be found advisable to reduce the continuous velocity of the sewage even to below six feet per second.

In fixing the gradients a careful distinction should be made between the slope of the bottom and the hydraulic slope, which is the free surface of the flowing water. While the bottom slope should be designed to give the least flow of sewage a proper velocity, the hydraulic slope, when the sewers have their maximum flow, should prevent a retardation due to junctions or to high water at the outfalls.

b. Shape and Size of Sewers.

The design of the sectional shape of a sewer should have for its object the concentration of the ordinary flow so as to increase the velocity and prevent the deposit of suspended matter. A flat bottom, for instance, allows the sewage to be spread out, the depth is reduced and consequently also the velocity.

The semi-circular form is the best section in this case for the flow of water. Where the flow varies considerably, as in the combined system of sewers, the egg-shape is a better form, because it gives an approximately semi-circular section for both small and large discharges. Where, however, the flow varies but slightly during the day, as in a separate system of sewers, it is preferable to adopt the semi-circular form and therefore circular sewers. In the few instances mentioned above, where a sewer is not expected to receive more than a small proportion of the computed quantity of sewage for a long time, it may be expedient to adopt an elliptical or egg form.

To give sewers their proper size is naturally of great importance.

If they are too small they will not carry the required quantity of water and will be liable to obstruction. If they are too large a useless expense will have been incurred and the flow will be more shallow and therefore more likely to facilitate deposits.

The smallest size that it is proper to give to your public sewers is a diameter of eight inches. A smaller size has occasionally been advocated, but experience has shown that no advantage is gained. It is true that a six inch pipe will remove the sewage from a large number of houses, but it is also true that, as experience has shown, these small pipes frequently become clogged up and cause trouble and expense in the removal of the obstructions. In England, experiments made by Latham show a remarkable difference in the number of stoppages occurring in a six inch and in a nine inch sewer, and there the latter size is employed as the minimum.

The least size to be given to house sewers is six inches, when they are made of clay pipe, and four inches when of iron pipe, which has fewer and more even joints. A six inch pipe is sufficient to carry off the sewage from a large dwelling house, and this size, if the public sewer is but eight inches, should therefore also be considered a maximum. When laying public sewers, it is proper to insert none but six inch branches for house connections, and in the case of specially large buildings, apartment houses or business blocks, to insert two of them.

The sizes should be computed on a basis of the maximum population which they are intended to serve. The quantity of sewage and of ground water allowed is given above for different existing conditions. For the maximum flow, the sewers should be computed to run not more than half full.

In making calculations for sizes, we have used Kutter's Formula, and assumed the value of n designating the degree of roughness, to be equal to .014. In constructing the sewers it will be found of great advantage to make the interior surface as smooth as possible, not only to reduce the coefficient of roughness, and therefore increase the capacity of the sewers, but also to prevent the adhesion of suspended matter which is liable to occur along the rough surface and by decomposition to cause foulness.

The sizes of the interceptors, as marked on the plan, are approximate and determined only for purposes of estimate. Before construction it will be necessary to carefully revise them. We give no sizes for the district sewers, as these can be easily determined when their exact locations are fixed.

c. Depth of Sewers.

The proper depth of sewers below the surface is governed by the usual depth of the cellars. Where possible, public sewers should be placed several feet below them so that the private sewers can freely discharge into them with a fall of at least $\frac{1}{4}$ inch per foot. In business districts the top of a public sewer is usually placed from 10 to 12 feet below the pavements, and in closely built up residence districts, nearly as deep. In the higher suburban districts, where cellar drainage is generally not demanded, the depth can be reduced, and is sometimes fixed at six feet. Where buildings are placed at a considerable distance back from the curb line, the depth of the public sewer must be sufficient to allow for the fall due to the increased length of the private sewers.

Interceptors should be laid deep enough to receive a free discharge from the district mains. But as they are generally laid across instead of in the valleys and depressions, their depth is sometimes considerable and at other times they are barely beneath the surface. The least depth in your city should allow for a covering of not less than eighteen inches—and better twenty-four inches—so as to prevent injury by frost or by traffic.

d. Alignment and Junctions.

The alignment of the branch and main district sewers is determined by the topography and by the local improvements. The mains will generally be placed along the lowest streets of the area. It may be found advantageous sometimes to place sewers in alleys instead of on the streets, because house connections may be made less expensive by carrying the sewer to the rear. But in view of the hilly nature of the territory it may seldom be possible to obviate the building of a sewer upon the street, and it may sometimes require also the placing of one in the adjoining alley, to receive the sewage from the buildings situated on the lower side of the street.

It is not only necessary to lay sewers with a perfect gradient, so as to obtain a regular velocity and prevent deposits, but it is also necessary that small sewers of 15 inches or less in diameter, should be laid perfectly straight in their direction, and that when a turn is necessary, it should be made entirely within a manhole. The advantage of this method of construction lies in the fact that every part of the sewer can then be inspected and, if necessary, cleaned from a manhole at any time.

The manholes should be conveniently located and provided with iron steps so that they can be easily descended. They should also be provided with locked covers, having openings for ventilation, and dirt pans under them to catch the dirt that falls through the openings. Such pans are of much more importance in a separate than in a combined system of sewers, and should, therefore, never be omitted. The dirt which they collect should be emptied regularly.

Where the gradients are sufficiently steep to allow of a drop at the manhole, it is best in that case even to lay pipes as large as 24 inches in diameter perfectly straight between the manholes. Larger sewers, when changing their directions, are curved with large radii. The impossibility of examining them directly from the manhole is not serious because they can be entered and thus inspected and cleaned.

The junctions of sewers form an important detail. When two or more streams are joined improperly, eddies occur and the suspended matter in the sewage deposits and accumulates. The streams should join each other in such a manner as not to meet undue retardation or resistance and so as to prevent eddies. The inverts should be of such relative heights that during the ordinary flow, the water surfaces of joining streams should have nearly the same height, so that one stream should not cause back water in the other. To overcome the loss of head in changing the direction, a corresponding fall should be given, particularly when the gradients are flat. The invert surfaces should continue until they naturally intersect and form between them what is called a *tongue*. The omission of the tongue always allows eddies to form and silt and filth to deposit. Where sewers cross drains in such a manner that one or the other needs siphoning, it is preferable to depress the sewer, and to preserve the grade of the drain for the better removal of the heavier silt carried along by it.

e. Ventilation.

The object of ventilating a sewer is two-fold:

First—The air, if confined within the sewer, is subject to compression and rarefaction by the rise and fall, and also by the change of temperature of the sewage. This variation of density in the sewer air often causes either a blowing out or a siphonage of the traps attached to the fixtures in the houses, and a consequent escape of foul air into the same. It is therefore necessary to maintain

atmospheric pressure within the pipes, or, in other words, a free communication with the outer air.

Secondly—The sewage in its daily rise and fall, due to the different rates of water consumption during the day and night, coats the sides of the sewer with matter carried in suspension. By decomposition this coating may evolve offensive gases. Sewage that is not fresh, but has been temporarily held back by imperfect design or construction of the pipes and fixtures within the buildings, or by an imperfect manner of cleaning the same, not to mention a retention in cesspools, likewise becomes offensive. It is therefore desirable to dilute the sewer air sufficiently to make the gases contained therein unnoticeable and to neutralize their bad effect.

The problem of sewer ventilation therefore resolves itself into a provision for maintaining a direct communication between the air in the sewers and the atmosphere, and in causing the entrance of pure air, and its circulation through the sewers, to be as free as practicable.

The most perfect way of accomplishing the above conditions, is to ventilate the public sewers through the house drains and soil pipes of the buildings, to omit a main trap along the house sewer, which also acts as a retainer of foul matter, and to have perforations in the manhole covers of the public sewers. In this way an abundance of air can enter the system, not only from the outfall, but through the manhole covers, and circulate through the sewers and out through every private sewer to above the roofs of the buildings.

Such a method of ventilation, however, requires that the entire plumbing in the house is planned and constructed by responsible parties, so that the work will be first-class. It is also necessary to have the house pipes tested after the plumbing is finished, so as to be assured of tight joints.

This method has been tried in several cities in our country, and is the common one of the continent of Europe. But it is not the usual one in our country, for there is in the minds of many a fear that if the public sewer should be ventilated through the soil pipe of their house, some danger might arise, through a leak in their own pipes, of contracting a disease, the germs of which are supposed to come from the public sewer.

From experience in our country and in Europe, these fears are not well founded and there are no facts on record to justify them. On the other hand, the advantages of a thorough draft through the

house pipes is considerable and keeps them much cleaner than where a trap is placed between the house and the sewer, thus disconnecting the two.

It has been said that air coming out of soil pipes below windows of adjoining houses might cause offense. But offense could also be caused if there were a main trap and the house pipes were foul, which they generally are not when used for ventilating the public sewers.

In those cities, however, where the municipal control of the house sewers cannot be secured it is deemed better to have such a trap and to confine the ventilation of the public sewers to whatever circulation is obtained from the openings in the manhole covers. It would be found in such a case, that near the upper end of your sewers the air would freely escape from these openings, and unless the sewers are kept scrupulously clean, its odor will be somewhat offensive, as observed in many cities. Then, when it becomes desirable to prevent this escape, there is no better practical way than by leading a special pipe from the manhole up to beyond the roof of an adjoining house, but with the practical difficulty of securing the proper rights.

A still less effective, though a somewhat palliative measure against the escape of the air at the highest manhole, is to hang a light rubber flap valve against the opening of the inlet pipe to the manholes below, which allows the sewage to flow by, but prevents much of the air from passing upwards into the pipe. By such means each section between two manholes is ventilated independently and the escaping air is likely to be less foul. If the sewers are kept properly cleaned, as they ought to be, the air should not be offensive or generally noticeable above the surface of the street.

It is often found that from a single new sewer offensive odors are at once emitted at the manholes, and this is also the case, even where an entire district is provided with new sewers. This objectionable feature may be due to the fact that at first but few house connections are made, and therefore an insufficient quantity of sewage is discharged to maintain a continuous flow, and thus deposits are allowed to form. The use of automatic flush tanks will, to some extent, obviate this trouble.

Escaping odor may also be due to the fact that the sewage comes from overflowing cesspools and is therefore in a foul condition. The trouble from this cause can, of course, not be prevented until

there is legislation compelling the abandonment of such cesspools and the substitution of a modern system of plumbing and a direct connection with the sewer.

f. Inspection and Flushing.

A sewerage system may be well designed and well built, but it will not give perfect satisfaction unless it receives periodical inspection and cleansing. No matter how carefully grades and junctions are arranged, deposits, and even obstructions, are nevertheless liable to occur. In order to prevent objectionable consequences, it is necessary to do three things:

First—There should be a municipal control over the connections with the houses and the general arrangement of sewage receptacles on private premises, so as to prevent the introduction of matter for the removal of which sewers are not intended.

Secondly—There should be a periodical inspection of the public sewers to discover any slight accumulation of matter, which by increasing in bulk, might ultimately result in a stoppage.

Thirdly—There should be a periodical cleansing by flushing the entire system.

These demands are of far more practical importance where the separate system is adopted than where the sewers must be built materially larger.

The prevailing and unfortunate custom in this country to undervalue the importance of keeping sewers clean should not be followed in your city, where with a separate system, which will be more extensive than any other now in use, a comparative neglect in providing proper means for cleansing, and thereafter in frequently and properly using them, would be followed by far more extensive troubles than elsewhere.

As the smaller sewers are laid perfectly straight between points of access, the inspection is not difficult. A lamp with a concave reflecting mirror is held at one point, and an observer stands at the other, holding a plain mirror at an angle of 45 degrees, so that when looking into it he can see the entire stretch of pipe between himself and the lamp. When sewers are large enough to be entered, inspection is equally easy.

The upper ends of the sewers, receiving but a small amount of sewage, are most likely to have deposits, on steep as well as on light grades, and need more frequent flushing than when the ordinary flow is greater. Flush tanks are therefore necessary at all the

heads. They are supplied with water from the city mains and may be automatic in their operation, discharging once or twice daily, or may be discharged by hand.

A flushing lower down the sewer is accomplished by inserting a plug at the manhole, which allows the sewage to accumulate in sufficient quantity behind it, and rush through the sewer when the plug is subsequently withdrawn. Special flush gates should be built into large sewers and used in a similar manner.

A very beneficial system of flushing, particularly the larger sewers, consists in the admission of a limited amount of roof water near the heads of the sewers, as already discussed under Section N. Separate System.

The interceptors having more deposit than the other sewers, on account of a reduced velocity, should be flushed by still other means. They should have large flushing tanks placed at their respective ends, each containing from 2,000 to 3,000 cubic feet of water, or even more, which can be discharged whenever demanded.

The western high level interceptor should have one built like a circular sewer of suitable diameter and length, at the point where it terminates at Gwynn's Run, and from which it should be fed. The eastern high level interceptor should have one near its head. It cannot readily be supplied either from Jenkins or Harford Run, and must, therefore, be filled from the public water supply. The western low level interceptor may have its flush tank fed by a special channel bringing water from either Gwynn's Run or Gwynn's Falls. The eastern low level interceptor may have its tank fed from the run discharging into the Gorsuch Creek, or, at a more distant future, from Herring Run. The interceptors from Locust Point, having less gradient than the others, should be provided with the largest flush tanks, and they will have to be filled from the public water supply.

There is another opportunity of flushing some of the mains and interceptors of the low level system of which advantage should be taken. Gates may be placed along the high level interceptors at points where its sewage can be temporarily passed down the main sewers of the low level system at will, and thence flow into the interceptor. A comparatively large and steady stream of sewage may thus be utilized with good effect and avoid the necessity of adding clean water to the sewage for this purpose, and thereby increasing the amount which must be lifted by the pumps and subsequently purified.

g. House Sewerage.

A few words should be added regarding what is considered a most important part of the system. The full benefit of a sewerage system can be experienced only when also that portion of it which extends into the houses and up to the various sewage receptacles, is properly designed and constructed. In fact, so far as the propagation of disease is concerned, the latter is more important than the public part of the system, because it brings any possible danger much nearer to the individual.

Usually the design and construction of the house sewerage works are left entirely in the hands of the property owner. We cannot too strongly urge that the custom prevailing almost universally in Europe, and already to some extent in this country, be adopted also in Baltimore, according to which the municipality has control of the general design and of the pipe arrangements within the buildings, and in some cases also of their construction. It must be admitted that the owners are usually obliged to rely upon an expert plumber or architect. But in many cases the cost of getting good advice cannot be paid, and among the poorer classes therefore defective plumbing is most often found.

To protect such citizens and their neighbors against the dangers arising from improperly arranged sewer pipes and fixtures within their houses, and also to guard the public sewers against misuse, it is now becoming customary to adopt and enforce so-called plumbing regulations and also to control the general design as well as the sewer connections. While assuring all reasonable liberty to the owner, he should be compelled to adhere to certain regulations, both for his own benefit, as well as for that of his neighbors.

R

STORM DRAINAGE SYSTEM.

It has already been stated that the rain-water must be carried off by a separate system of drains. You have already constructed many of such drains and they discharge into the several water-courses within the city limits and into the harbors.

Some data concerning the existing drains were furnished us, but the available information is scant. There is some uncertainty as to the actual boundaries of several of the drainage areas, as taken

from the maps furnished to us. It is said that sometimes the actual areas are known to differ from those obtained from the contour survey, and that therefore artificial boundaries exist. Further, there are now relief drains in some instances which run from one area into another, and thus complicate the system; and there are instances where parallel drains exist within the same area. It is not possible to determine from the maps what proportion of the water is received by each of them. Conditions required a consideration from us that are liable to change from time to time and affect the location of drains.

In view of these uncertainties, it was found impracticable to design a general system so far as the actual alignment is concerned. But in our opinion it is sufficient for present purposes to discuss the questions in such a manner so as to establish the general principles that should be adopted, and according to which it will be a very simple matter for local engineers to determine the location and design of any particular drain at the time when this may be required.

The following, therefore, gives the principles upon which, in our opinion, the draining system should be based.

As the contents of the drains carrying only rain-water and sub-soil water, are not offensive, because any sewage which now enters the same will be excluded, the outfalls can be placed at the most convenient points along the shore.

Inasmuch as drains are mostly of large size, their direction should be as short as possible to the outfall. They should also be placed as nearly as possible along the lowest territory of the area. It will be found economical to concentrate the water as soon as possible into large drains, instead of endeavoring to build several drains of a smaller size.

In view of the expense of the main drains, and from the fact that they are often not built until the territory has been laid out, it would be well to settle upon the most economical lines at an early day, in order to secure the necessary property thereon, and it will also in some cases be found economical and expedient to lay out a street along the lines found best for the drains.

Regarding the sizes, they should of course be sufficient to carry off the water from the heaviest storms, and therefore be proportioned for the run-off, which has already been discussed.

When building drains through lower and already well built-up districts, it is hardly necessary to say that they should be propor-

tioned for the future condition of the entire drainage area, although the upper parts of it may now be sparsely populated.

Regarding the shape of the drains there is little to be said in addition to what has already been said regarding the shape of the sewers, excepting that in the absence of foul liquids, it is not as necessary to concentrate the flow as it is in the case of sewage. There being usually but little head available in the lower parts of the city, where we naturally find the largest drains, the sectional shape will of necessity be wide and shallow. If found practicable, it is preferable, instead of having a perfectly level bottom, as in the present large drains, to have a slightly V-shaped bottom, formed either of timber or concrete, by which a more thorough removal of the deposit by the natural flow of the stream may be expected.

The gradients of the drains will in your city be partly very flat and partly quite heavy. The usual formulae will indicate what the least gradient should be for any particular drain, taking into consideration the fact that many storms will bring in silt, and if the velocity is insufficient, will deposit and tend to fill the drains. In their design, consideration should also be given to the hydraulic gradient of the water during the heaviest storms, which should in no case rise to such an elevation as to cause flooding. It is at times when the capacity of the drains is most severely taxed that the advantages of a proper design are most decidedly felt.

In some parts of the city the drains will naturally have very steep grades. In some instances it may be found advisable, as in the case of sewers, to insert drops along the lines of the drains, in order to break an excessive velocity which might tend to destroy them. While a continuous flow of six feet per second is deemed a maximum velocity, an occasional flow, such as during rainstorms, can safely be increased to twelve or even fifteen feet per second, when however, the drains must be built of great strength.

It would be well for the city to have authority to establish the grades of those streets upon which main drains will be required in the future, before the property is being improved by erecting buildings and by paving. The construction of drains is sometimes made quite difficult by the fact that the streets are not only improperly laid out, but also improperly graded to suit the future demands for draining the territory.

The admission of rain-water from the streets should be obtained through inlets placed more frequently than at present, so as to reduce their size and avoid the unsightly and dangerously large

openings now existing along the streets. It will be evident, that the more frequently they are placed, the less water will accumulate at the foot of a hill, and therefore, the smaller the opening need be.

We are also of the opinion that the inlets should not be provided with catch-basins to retain the silt or whatever may be washed into them. The object of such basins is to intercept the heavy matter and periodically cart it away, instead of allowing it to reach the drains and there to deposit. Catch-basins, even after the sewage flow no longer exists in the gutters, are still apt to get foul because of the organic matter washed from the streets. Such foulness is less offensive in the drains than in the catch-basins, which are situated at the sidewalks, and where it is much more likely to be observed. Also, it is found impracticable to intercept all matter in the catch-basins which would deposit in the drains after they reach the flat grades in the lower part of your city. The cleaning of the drains would, therefore, be necessary in any event, and the additional amount of silt that would otherwise be intercepted by the catch-basins, will not cost much more to remove.

In the city of Paris, even though a combined system of sewers is used, it is not found objectionable to allow all the street dirt to enter the sewers and therefore the catch-basins at the inlets are omitted.

While we recommend that no catch-basins shall be used, we also recommend the disuse of traps, excepting in special cases, where it may be found desirable. Where one is required, it can be made in the form of a mechanical or swinging trap, rather than a water trap, which necessarily implies a catch-basin. A hanging trap, although not entirely excluding the air, is entirely sufficient, when applied to a drain from which the sewage is excluded, and where, in the worst cases, but a slight odor will exist in the drain that would not be noticed when a hanging trap is used.

The question of ventilation of drains receives a very simple solution by the omission of traps from the inlets, as there will be a continual circulation of air, which, if sewage is excluded, will not cause offense. The comparatively large size of the drains, and the consequent abundance of circulating air, can only in cases of gross carelessness, or under extraordinary conditions, permit of any objectionable odor. The first part of a rainstorm brings in the dirtiest water, which, during the latter part, is usually carried to the outfall. The use of traps prevents a proper circulation of air, and therefore a proper oxidation of whatever foul matter may have remained.

The sudden entrance of water from the rainstorms will necessarily compress the air in the drains, and force it out at points where the resistance is least. The escape of air at such times would, therefore, be far more objectionable than when the drains are continuously exposed to natural ventilation.

It is quite material that the bends or turns of drains and the junctions of two or more of them should be properly designed, so as to prevent any reduction in the velocity of the water during the greatest discharge. If there is an obstruction, caused by an improperly built junction, it will affect the discharging capacity by reducing it in the stretch above the obstruction. Therefore, to obtain the full benefit of the carrying capacity of the drain itself, the design should be carefully made with a view of not retarding the velocity of the water at any point.

In order to prepare for the proper location and design of drains when they may be required here and there, a map should be made showing the actual outlines of the drainage areas, the character of the territory as to its degree of perviousness, and the practical lines for main and branch drains, which are consistent with the existing drains, and with the engineering requirements as mentioned above, and also with other local requirements which are not at present apparent to us.

S

SUB-DRAINAGE SYSTEM.

The necessity for pumping and treating the sewage makes it, of course, economical to prevent from getting into the sewers any water that is not foul and does not require purification. It is, therefore, advisable to prevent sub-soil water, as much as possible, from finding its way into them. These should, therefore, be constructed as water-tight as practicable. But, inasmuch as a sub-drainage of the soil is desired, and is in fact necessary in some parts of the city so as to prevent wet cellars, a proper provision should be made for it.

In the higher parts of the city, a collection of the sub-soil water will not be difficult. Where required, special drains can be laid with sufficient depth to accomplish this purpose and discharge into the rain-water drains at a sufficient height so that an annoyance by back water during heavy storms will not be felt.

In the low sections of the city, however, near the wharves, a different treatment is necessary. The sewers in that section of the city will be built below tide level, and low enough to collect the sub-soil water. Inasmuch as it would occupy space of the interceptor intended for sewage removal, and also require pumping and delivery at the filtration area, it is best not to use the sewerage system for its collection. A separate system of sub-soil drains can be readily laid in that part of the city to comply with the demands of cellar drainage. The water would undoubtedly have to be collected below high water level, and it would, therefore, be necessary to pump it. Unless other and special provisions can be made, it will be found best to lay these sub-drains when building the low level interceptor, one on each side, and deliver the sub-soil water also at the pumping station, where special pumps can lift it and discharge it into the harbor.

The additional expense of thus treating the sub-soil question in the low parts of the city will, therefore, not be very great. The plan of the pumping station includes a provision for pumping this water from the low territory between Washington street in the east, to Gwynn's Falls in the west.

The allowance made for the quantity of sub-soil water which may enter these special drains of the low territory, as discussed above in Section "E," is 1,200 gallons per acre per day. The sizes of the drains, where built along the interceptors, range from 8 inches to 24 inches diameter on each side, and the branches should gradually diminish to 3 inches diameter.

The allowance which it was thought proper to make for the leakage of sub-soil water into the sewerage system itself, and which would therefore reach the interceptors, is fixed at 160 gallons per acre per day.

T

ESTIMATES OF COST OF THE SEWERAGE SYSTEM.

No soundings of the ground nor special surveys have been made for the purpose of estimating the cost of the works that have received consideration. The character of the foundations has been determined only from general information. We have endeavored to make the estimate of cost on a safe basis where uncertainties exist. The unit prices are ample and some of them may perhaps be reduced.

The cost of the local or district sewers, collecting the sewage from buildings, is the same for any system of disposal. A detailed design of the local system was neither contemplated nor practicable with the information on hand. As it is usual for the adjoining properties to be assessed for the cost of local sewers, we further considered it to be of no value in arriving at the expense of interception and disposal, after the sewage had been collected, which expense alone falls upon the city at large.

As the important questions before us related to the best manner of interception and disposal, we give the cost of the local or district sewers per square mile of territory, and we selected two conditions, namely, the densely built-up parts and the suburban parts of the city. The cost is based in both cases upon the average length of streets and alleys within a square mile and included both mains and laterals. The excavation is supposed to be in earth and all works done in a thorough manner. House pipes are not included, but merely a Y branch in the sewer at which they connect. All streets are supposed to have been paved.

This information will be sufficiently close to gain a fair idea of the expense in any district which it is desired to sewer.

We have assumed that in the business districts there will be about thirty miles of sewers, and in the suburban districts about ten miles of sewers in a square mile. The cost per square mile in the former would be about \$480,000, and in the latter about \$110,000.

The estimates of cost for the interception and disposal of the sewage has been made, both for immediate needs, and for such a time when one million persons contribute to it. The former represents the amount of money required for the different projects at the outset; the latter, for the purpose of comparing the eventual cost of the several projects which have been examined.

Statement A gives the expense of constructing the works, Statement B, the annual expense of operating them, the interest, renewals, etc. The latter statement allows a fair comparison to be made between the economy of the several projects.

Some parts of the work, when once built, will answer for all time, so far as their capacity is concerned. The interceptors, for instance, are expected always to serve the territory for which they are intended. The outfall sewer of the dilution and precipitation projects would at once answer for discharging the sewage from one million people. Some parts will have to be added to later, such as the pumping machinery. Still other parts may have to be

abandoned later, should, for instance, a temporary chemical disposal plant be placed on the shore of the Patapsco River, near the line of the discharge mains to Glen Burnie.

A summary of the estimates of cost is inserted herewith. The detailed estimates of cost will be found in the Appendix. It will be noticed that the dilution project is the least expensive one, both for immediate and future needs. The filtration project is the most expensive one in both cases.

Were the basis of cost to be the only criterion upon which to reach a decision, the project of disposing of the sewage by dilution in Chesapeake Bay would have to be preferred.

SUMMARY OF ESTIMATES OF COST.

	A	B
	Construction, Total Cost.	Maintenance, Inter- est and Renewals per annum.
1. <i>Dilution</i> : Project.		
<i>a.</i> For immediate needs	\$3,880,167	\$213,700
<i>b.</i> For one million persons	5,129,167	290,460
2. <i>Precipitation</i> :		
<i>a.</i> For immediate needs	\$2,962,000	\$284,400
<i>b.</i> For one million persons	5,503,000	665,000
3. <i>Filtration</i> :		
For immediate needs with		
<i>a.</i> Temporary precipitation . . .	\$3,019,012	\$301,355
<i>b.</i> Filtration at Glen Burnie . . .	5,741,007	402,752
<i>c.</i> For one million persons	12,171,803	913,044

U

RECOMMENDATIONS.

The several ways in which the sewage question, as related to the City of Baltimore, can be solved, have been discussed above. The conditions which govern the solution are clearly set forth. Each one of the projects which satisfies them, has been worked out so as to give results as satisfactory as practicable.

The collection of the sewage from private premises, we find to be preferably accomplished by means of a separate system of sewers into which no street water is to be admitted.

The collection and disposal of the rain-water we find should be accomplished substantially in the same manner in which it is done at present, with a modification of some details.

The final disposal of the sewage required the consideration of three methods, which are all applicable and according to any of which the sewage can be disposed of without offense. Some of them are better than others.

We unhesitatingly state that, irrespective of cost, the purification of the sewage by filtration through sand is the best method, because it effectually destroys all decomposable matter within a short time after the sewage is delivered upon the fields. It enables the sewage to increase the fertility of land for agricultural purposes and to guard against crop failures from droughts. It causes no objectionable results, either on the fields themselves, or after the purified sewage drains away from them, if the works are properly laid out and fairly well managed.

The operation of filtration fields requires labor of no great skill, and good results can be secured whether crops are raised or not.

Both the precipitation and dilution methods are less satisfactory, because in the former case greater attention must be given to the treatment, if a nuisance is to be prevented, and in the latter case there is a danger to some of the oyster beds, and a pollution of the Bay for a considerable distance from the outlet.

As on the Berlin sewage farms are located public institutions, including homes for convalescents and paupers, who are employed upon the fields, and as the Rhode Island State Institutions in Cranston use their inmates to care for the sewage farms connected therewith, so could the filtration territory of Baltimore contain similar institutions, upon which convict and pauper labor might be utilized in a very satisfactory way to materially reduce the cost of distributing the sewage and for attending the farms.

We believe that it is the desire of your citizens to adopt the best method of disposing of the sewage and that they are willing to pay a larger sum for it than for others which are less good. The experience in other cities has generally shown that both precipitation and dilution methods were on the whole less satisfactory than the filtration method, and they are now recommended only for such cities where filtration is impracticable.

As we fully believe that your intelligent citizens will not regret a greater outlay for a greater benefit, we do not hesitate to recommend to you the filtration system.

In closing, we desire to convey our thanks for many courtesies received while studying the problem, from yourselves, from Mr. Kenneth Allen, C. E., principal assistant, and Mr. Rector, secretary, and from others who have contributed information regarding the subject.

Respectfully presented,

RUDOLPH HERING,
SAMUEL M. GRAY.

V

APPENDIX I.

GEOLOGY OF BALTIMORE AND THE REGION ADJACENT TO THE LOWER PATAPSCO RIVER.

By WM. BULLOCK CLARK, State Geologist.

The State of Maryland is divided into three clearly defined regions, known respectively as the Coastal Plain, the Piedmont Plateau and the Appalachian Region, each of which contains definite physiographic and geologic features which characterize it. The City of Baltimore is situated near the boundary line of the first two districts, its higher portions resting upon the rocks of the Piedmont Plateau, while its lower portions occupy the landward border of the Coastal Plain.

THE PIEDMONT PLATEAU.

The Piedmont Plateau, which lies along the eastern flank of the Appalachian Region and occupies the country lying between Baltimore and the Frederick Valley, is the southward extension of a continent of early geological time, the main body of which was largely within the limits of the British possessions of the present day. Toward the south it existed as a narrow belt that continued almost to the Gulf border. The rocks composing it are more or less crystalline, while the structure throughout is highly complicated. Within the limits of Maryland the rocks of the Piedmont Plateau are divisible into two distinct classes. In the eastern

portion of the region, in the vicinity of the City of Baltimore, they are completely crystalline, physical and chemical changes of such moment having taken place in both the ancient sediments and the eruptive rocks that penetrate them as to often obscure their original characters. In the western portion, on the other hand, the rocks are semi-crystalline, and while they have been subjected to a certain amount of metamorphism and alteration, they still plainly show that they were once sediments of an ordinary type.

It is upon the more highly crystalline rocks of the Piedmont Plateau that the City of Baltimore is situated. These various rock masses may be divided into six distinct types, three of which are of undoubtedly eruptive origin (gabbro, peridotite or pyroxenite, and granite), while the other three (gneiss, marble and quartz-schist), although at present exhibiting no certain traces of clastic structure, were probably sedimentary. Through these latter rocks the eruptives penetrated.

The gneiss is the prevailing rock of this area. It extends as a band from the northeast to the southwest, constantly narrowing southward, and shows great complexity of structure. The gneiss is sometimes quite constant in character for considerable distances, but more usually it consists of a succession of differently constituted layers. It may have had its origin in the impure sand deposits of early geological time.

The marbles are found intercolated in the gneiss complex, occurring as irregular and disconnected masses that show at a glance how intricate the stratigraphy really is. Although found to the north of Baltimore and at no place within the city limits, they form part of the same rock series and cannot be ignored in a discussion of it. They are much more coarsely and perfectly crystalline than the marbles and limestones of the more western portion of the State, and have lost all evidence of an original clastic structure. On account of their greater solubility they have been easily removed and now form depressions as the Green Spring, Dulaney and other valleys which are sharply bounded by the surrounding ridges of gneiss. As in the case of the gneiss, it is highly probable they were originally sedimentary accumulations rich in carbonate of lime.

The least important of the rocks of probable sedimentary origin in the Baltimore region, is the peculiar quartz-schist composed chiefly of quartz and divided into beds of various thicknesses by parallel layers of muscovite. The quartz grains are of different sizes, but are so completely re-crystallized that they form an inter-

locking mosaic. The quartz-schist never attains any great thickness. Whatever the origin of the quartz-schist may have been, it is closely allied to the gneiss into which it grades by imperceptible transitions. It is, however, always sharply defined against the limestones. It is not improbable that this rock represents facies of the gneiss produced by some dynamic agency.

The three types of eruptives have all broken through and have more or less modified the rocks just described, and are hence younger in age. The oldest, as well as the most extensive of the three eruptive rocks which so abundantly intrude the gneiss complex, is the gabbro. Its black color has given to it locally the name of "nigger-head rock." The action of pressure which has caused the re-crystallization of the gneiss and marble is also very marked in the gabbro. It has caused its iron magnesian constituent pyroxene, to change to another green mineral called hornblende. This has in some cases left the rock as massive as before, and in other cases it has rendered it schistose. This resulting rock is called gabbro-diorite.

The next eruptive rocks in point of age are the basic-magnesia silicates, peridotite and pyroxenite and their alteration products serpentine and steatite. These rocks are intimately associated with the gabbros. They do not occur in as large masses as the other eruptive rocks, but occupy numerous smaller areas.

The youngest intrusive rocks are the granites. They also form numerous detached masses. The granites are so like the surrounding gneiss in chemical, as well as mineralogical, composition that when they have been greatly foliated through dynamic action it becomes a matter of no small difficulty to distinguish them. The gneisses of the Baltimore region are penetrated with a great abundance of dykes, veins and "eyes" of the coarse-grained granite known as pegmatite. The other crystalline rocks of the region, although to a less extent, contain the same material.

It will thus be seen that the ancient rocks which form the foundation upon which the City of Baltimore is situated exhibit a great variety of types which show highly complicated structures. They were very fully studied by the late Prof. Geo. H. Williams, and the above statements are very largely adapted from his writings.

THE COASTAL PLAIN.

The Piedmont Plateau is overlain upon its eastern margin by a series of geological formations of much more recent date, the mate-

rial out of which they are formed having been for the most part derived from the more ancient rocks to the westward. These materials were carried down by the streams from the old continent and distributed by currents along the margin of the continent, at the time when the old shore-line was found in the vicinity of the City of Baltimore. These later sediments form a series of thin beds which are inclined slightly to the eastward, so that successively later formations are found in passing from the interior toward the coast. Although deposition undoubtedly went on throughout these later periods along the margin of the Piedmont Plateau, oscillations of the sea-floor were constantly going on, so that the formations along their landward margins were constantly raised above the level of the water and subjected to eroding influences. As a result, these deposits, in the vicinity of the Piedmont Plateau, present much complexity. Furthermore, the denuding effects of more recent time have left numerous remnants of them as detached masses upon the old crystalline rocks.

The later formations are composed of a succession of sands, clays, and marls that carry with them the remains of the animal and plant life that were entombed at the time they were deposited. The evidence presented by the succession of organic forms, together with the varying physical conditions of deposition, afford criteria upon which a satisfactory classification of the formations may be made.

THE CRETACEOUS (POTOMAC).

The oldest of the Coastal Plain formations is of lower Cretaceous age, and is known as the Potomac formation. It directly overlies the crystalline rocks of the Piedmont Plateau and is to a considerable extent formed of debris from them. The deposits consist chiefly of sands and clays with gravels at certain points where the shore accumulations are still preserved. Throughout the lower members there is a constant alternation of sandy and clayey layers which also show a horizontal gradation into one another. The sandy layers are often much limited in extent, being commonly found as lenticular masses, which rapidly diminish in thickness from their centres. Highly colored and variegated clays are found in the upper portion of the lower Potomac, and have yielded large amounts of nodular carbonate of iron. The upper Potomac is composed of more persistent beds of clay and sand, the prevailing deposit being a moderately coarse white sand that at times exceeds one hundred feet in thickness.

The Potomac formation constitutes the main portion of the long necks which extend eastwardly from Baltimore, burying from view the rocks of the Piedmont Plateau and in turn underlying the more superficial deposits of recent geological date. The ancient crystal-line floor upon which these deposits rest reaches a constantly deeper level in passing from its eastern edge beneath the Coastal Plain. Although frequently out-cropping in the centre of the city, and in the regions to the north and south of the same, these old rocks are found several hundred feet below the surface at the eastern extension of all the necks adjacent to the Patapsco River. The Back River and Patapsco River necks differ very materially in their geological structure from those to the south of the Patapsco in that the upper sandy members of the upper Potomac formation are entirely wanting from the former, while they occur in their full and normal development in the area of Stony and Rock Creeks in the Magothy peninsula, and throughout the region to the south of it.

The later formations of upper Cretaceous and Tertiary age, succeeding the Potomac formation in the eastern section of the State, and with here and there scattered remnants reaching almost to the borders of the Piedmont Plateau, are wanting in the region now under discussion. That most, if not all, of them formerly reached well within the limits of the city there can be but little question, but they have long since been removed by the processes of erosion. The deposits of the latest geological epoch are, however, fully represented and will be further described.

THE PLEISTOCENE (COLUMBIA).

Superficially overlying the other formations of the Coastal Plain are deposits of Pleistocene age which have been described under the name of the Columbia formation. They consist of gravels, sands and clays. They nowhere attain any great thickness, but give evidence of rapid accumulation in a geological epoch of short duration as compared with the Cretaceous and Tertiary periods previously mentioned. The deposits give evidence of two periods of submergence, during which the deep valleys, which had been carved out in late Tertiary time, were to a considerable extent blocked with debris, which has, up to the present, never been wholly removed. The earliest of these submergences reached well within the present limits of the city, admitting of the deposition of considerable deposits of gravel and sand over the uneven sea floor composed both of crystalline rock and Potomac strata. After an

interim of brief elevation came a second submergence, of less extent, which covered the lower elevations within and to the east of the city, the sands and loams which were deposited forming a superficial coating of the country. The Columbia deposits, both of earlier and later date, have already been removed by natural processes from considerable sections of the country, both within and to the east of the city, laying bare, as in the vicinity of Stony and Rock Creeks, the great deposits of sand of the upper Potomac.

This brief statement of the geology of the Baltimore area would be incomplete without some mention of the history of the Patapsco River and its branches. Although that portion of the river system which crosses the crystalline rocks of the Piedmont Plateau may have existed prior to the submergence which brought about the deposition of the Potomac formation, yet its eastward extension, across the deposits of the Coastal Plain, is of far more recent origin. As was mentioned above, the carving out of the present valleys was accomplished by the streams at or near the close of the Tertiary. At that time the waters of the Susquehanna passed through the valley of the present Chesapeake Bay to and beyond the Capes, while the Patapsco River flowed in a deep valley to the main stream. Since that time various oscillations, recorded in the deposits of the Columbia formation, took place, finally leaving the Chesapeake Bay and the lower portion of the Patapsco as submerged valleys of the ancient rivers. As in the case of many of the other streams of the Coastal Plain, they become far less extensive bodies of water, and even insignificant streams, after the head of tide has been reached. It is also probable that along the line (so-called "Fall line") separating the Coastal Plain from the Piedmont Plateau a further depression took place in late geological time to more fully accentuate the difference.

From this brief summary it will be seen that the City of Baltimore and its vicinity comprises geological formations of widely different age and character, and has passed through a long cycle of varying physiographic and geologic changes.

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APPENDIX II.

List of rainfalls occurring during the past 25 years or more in Baltimore and other places in Maryland, in Washington, D. C., and in Philadelphia, Pa., having a duration of 10 minutes or more, and

a rate equal to or greater than one inch per hour. Some storms of long duration, but of less rate than one inch per hour, have also been added. The storms marked by a star (*) were recorded by automatic gauges, and in such cases storms of less rate than two inches per hour have been excluded.

Place.	State.	Date.	Amount in inches.	Duration		Rate in inches per hour.
				H.	M.	
*Washington, D. C...	June	30, 1895	1.06	0	10	6.36
Philadelphia, Pa. ...	July	23, 1887	0.92	0	13	4.25
Washington, D. C...	July	26, 1886	0.70	0	10	4.20
*Philadelphia, Pa. ...	April	16, 1891	0.67	0	10	4.02
Philadelphia, Pa. ...	August	31, 1888	0.80	0	12	4.00
Chestertown, Md. ...	August	15, 1894	1.85	0	30	3.70
Washington, D. C. ...	August	10, 1878	0.80	0	13	3.69
Philadelphia, Pa. ...	August	8, 1888	0.90	0	15	3.60
*Washington, D. C. ...	August	6, 1889	0.60	0	10	3.60
Washington, D. C....	Sept.	16, 1888	1.19	0	20	3.57
Washington, D. C....	Sept.	3, 1882	1.03	0	18	3.43
*Washington, D. C....	July	2, 1890	0.57	0	10	3.42
Washington, D. C....	Sept.	12, 1887	0.62	0	11	3.38
Washington, D. C....	July	1, 1884	0.56	0	10	3.36
Washington, D. C....	July	28, 1877	0.78	0	14	3.34
*Washington, D. C....	August	1, 1890	0.55	0	10	3.30
*Baltimore, Md.	July	16, 1895	0.55	0	10	3.30
Washington, D. C....	August	6, 1889	0.55	0	10	3.30
Washington, D. C....	April	28, 1878	0.82	0	15	3.28
*Philadelphia, Pa. ...	August	21, 1890	0.53	0	10	3.18
*Washington, D. C....	July	14, 1892	0.53	0	10	3.18
*Washington, D. C....	June	21, 1891	0.52	0	10	3.12
Washington, D. C....	July	29, 1877	1.44	0	28	3.09
Philadelphia, Pa. ...	May	20, 1889	1.00	0	20	3.00
Philadelphia, Pa. ...	August	4, 1889	1.00	0	20	3.00
Washington, D. C....	June	7, 1881	0.60	0	12	3.00
*Philadelphia, Pa. ...	April	16, 1891	0.50	0	10	3.00
*Washington, D. C....	July	15, 1891	0.50	0	10	3.00
*Philadelphia, Pa. ...	August	28, 1891	0.50	0	10	3.00
Washington, D. C....	August	25, 1885	0.50	0	10	3.00
Washington, D. C....	August	9, 1889	0.50	0	10	3.00
Washington, D. C....	June	10, 1876	1.98	0	40	2.97
Philadelphia, Pa. ...	Sept.	21, 1882	1.20	0	25	2.88
Washington, D. C....	July	15, 1886	0.72	0	15	2.88
Washington, D. C....	August	6, 1878	1.00	0	21	2.86
Washington, D. C....	July	9, 1888	0.99	0	21	2.83
*Baltimore, Md.	Sept.	8, 1894	0.47	0	10	2.82
Washington, D. C....	May	27, 1882	0.70	0	15	2.80
Philadelphia, Pa. ...	Feb.	18, 1887	0.51	0	11	2.76
*Baltimore, Md.	August	31, 1895	0.46	0	10	2.76

Place.	State.	Date.	Amount in inches.	Duration		Rate in inches per hour.
				H.	M.	
Washington, D. C....	August	5, 1878	2.08	0	46	2.71
*Washington, D. C....	July	1, 1889	0.45	0	10	2.70
*Washington, D. C....	June	22, 1890	0.45	0	10	2.70
*Washington, D. C....	Sept.	11, 1890	0.45	0	10	2.70
*Washington, D. C....	October	19, 1891	0.45	0	10	2.70
*Baltimore, Md.	May	23, 1894	0.45	0	10	2.70
*Philadelphia, Pa. ...	May	28, 1894	0.45	0	10	2.70
*Philadelphia, Pa. ...	August	2, 1894	0.45	0	10	2.70
Washington, D. C....	June	7, 1881	1.61	0	36	2.67
Washington, D. C....	June	3, 1883	0.66	0	15	2.64
Washington, D. C....	July	17, 1883	0.79	0	18	2.63
Washington, D. C....	July	1, 1889	0.65	0	15	2.60
*Philadelphia, Pa. ...	Sept.	14, 1892	0.43	0	10	2.58
Philadelphia, Pa. ...	July	23, 1887	1.86	0	44	2.54
Philadelphia, Pa. ...	July	6, 1884	0.50	0	12	2.52
Washington, D. C....	October	4, 1877	1.08	0	26	2.49
Washington, D. C....	July	18, 1871	0.83	0	20	2.49
*Washington, D. C....	June	27, 1892	0.40	0	10	2.40
*Baltimore, Md.	August	29, 1893	0.40	0	10	2.40
*Baltimore, Md.	June	12, 1894	0.40	0	10	2.40
Philadelphia, Pa. ...	Nov.	23, 1884	0.40	0	10	2.40
Pocomoke City, Md..	April	27, 1895	1.59	0	40	2.38
Washington, D. C....	August	11, 1887	0.71	0	18	2.37
Washington, D. C....	Sept.	25, 1872	1.18	0	30	2.36
Washington, D. C....	August	21, 1888	0.59	0	15	2.36
*Philadelphia, Pa. ...	July	3, 1892	0.39	0	10	2.34
Woodstock Coll., Md.	May	19, 1878	2.00	0	52	2.31
Washington, D. C....	June	23, 1888	0.50	0	13	2.31
Washington, D. C....	June	3, 1883	0.46	0	12	2.30
Washington, D. C....	July	3, 1871	1.13	0	30	2.26
Philadelphia, Pa. ...	July	23, 1887	2.25	1	00	2.25
Barren Crk. Spgs., Md.	May	20, 1889	2.25	1	00	2.25
Washington, D. C....	July	29, 1878	0.95	0	26	2.19
Baltimore, Md.	July	11, 1884	3.75	1	43	2.18
*Washington, D. C....	April	11, 1891	0.36	0	10	2.16
*Baltimore, Md.	July	6, 1894	0.36	0	10	2.16
*Philadelphia, Pa. ...	April	9, 1895	0.36	0	10	2.16
Philadelphia, Pa. ...	June	12, 1895	0.36	0	10	2.16
Philadelphia, Pa. ...	July	26, 1887	1.16	0	33	2.11
Wood Lawn, Md....	August	11, 1875	2.10	1	00	2.10
*Washington, D. C....	June	10, 1889	0.35	0	10	2.10
*Washington, D. C....	May	30, 1890	0.35	0	10	2.10
*Washington, D. C....	Nov.	23, 1891	0.35	0	10	2.10
*Philadelphia, Pa. ...	Sept.	8, 1894	0.35	0	10	2.10
Washington, D. C....	June	27, 1885	0.35	0	10	2.10
Washington, D. C....	June	14, 1888	0.38	0	11	2.07
Washington, D. C....	July	30, 1878	1.10	0	32	2.06

Place.	State.	Date.	Amount in inches.	Duration		Rate in inches per hour.
				H.	M.	
Philadelphia, Pa. . . .		Sept. 16-17, 1888	0.55	0	16	2.06
*Philadelphia, Pa. . . .		August 25, 1892	0.34	0	10	2.04
*Philadelphia, Pa. . . .		Sept. 14, 1892	0.34	0	10	2.04
Philadelphia, Pa. . . .		August 23, 1888	0.34	0	10	2.04
Fort McHenry, Md..		July 11, 1884	3.54	1	45	2.02
Sandy Springs, Md...		July 5, 1880	5.00	2	30	2.00
Cambridge, Md.		July 31, 1893	4.00	2	00	2.00
Sandy Springs, Md..		July 19, 1878	2.00	1	00	2.00
Washington, D. C....		August 11, 1873	1.00	0	30	2.00
Philadelphia, Pa. . . .		August 3, 1885	2.80	1	25	1.98
*Philadelphia, Pa. . . .		Sept. 5, 1891	0.33	0	10	1.98
*Philadelphia, Pa. . . .		June 21, 1892	0.33	0	10	1.98
Washington, D. C....		July 21, 1886	0.46	0	14	1.97
Philadelphia, Pa. . . .		August 31, 1889	1.17	0	36	1.95
Washington, D. C....		August 18, 1875	0.78	0	24	1.95
*Washington, D. C....		August 24, 1891	0.32	0	10	1.92
*Philadelphia, Pa. . . .		Sept. 15, 1893	0.32	0	10	1.92
Washington, D. C....		July 29, 1877	2.33	1	18	1.78
Baltimore, Md.		August 21, 1890	1.96	1	10	1.68
Emory Grove, Md....		May 15, 1879	5.00	3	00	1.67
Easton, Md.		July 21, 1894	3.04	2	00	1.52
Washington, D. C....		July 29, 1865	4.92	3	15	1.51
Philadelphia, Pa. . . .		July 6, 1884	1.50	1	00	1.50
Baltimore, Md.		August 22, 1887	1.74	1	10	1.49
Washington, D. C....		October 4, 1877	1.49	1	00	1.49
Philadelphia, Pa. . . .		August 1, 1878	1.43	1	00	1.43
Washington, D. C....		July 26, 1886	2.23	1	35	1.41
Woodstock Coll., Md.		August 21, 1890	2.80	2	00	1.40
Washington, D. C....		October 23, 1875	1.40	1	00	1.40
Washington, D. C....		October 23, 1876	1.40	1	00	1.40
Washington, D. C....		July 26, 1879	1.73	1	15	1.38
Washington, D. C....		October 26, 1879	1.73	1	15	1.38
Emory Grove, Md....		October 22, 1878	4.00	3	00	1.33
Easton, Md.		Sept. 19, 1895	1.33	1	00	1.33
Baltimore, Md.		August 10, 1873	1.30	1	00	1.30
Philadelphia, Pa. . . .		August 9, 1874	1.30	1	00	1.30
Washington, D. C....		August 29, 1874	1.30	1	00	1.30
Washington, D. C....		August 29, 1875	1.30	1	00	1.30
Washington, D. C....		July 26, 1886	3.14	2	27	1.28
Washington, D. C....		June 30, 1895	1.28	1	00	1.28
Philadelphia, Pa. . . .		July 12, 1878	1.27	1	00	1.27
Solomon's, Md.		August 20, 1893	1.47	1	10	1.26
Philadelphia, Pa. . . .		July 10, 1876	1.25	1	00	1.25
Oldtown, Md.		August 6, 1895	1.25	1	00	1.25
Baltimore, Md.		June 27, 1892	1.23	1	00	1.23
Washington, D. C....		October 29, 1885	1.20	1	00	1.20
Baltimore, Md.		May 20, 1889	1.20	1	00	1.20

Place.	State.	Date.	Amount in inches.	Duration		Rate in inches per hour.
				H.	M.	
Taneytown, Md.	July	1, 1892	1.20	1	00	1.20
Woodstock Col., Md..	August	22, 1887	1.56	1	21	1.16
Philadelphia, Pa. ...	August	21, 1890	1.16	1	00	1.16
Jewell, Md.	Sept.	16, 1888	3.75	3	15	1.15
Washington, D. C....	Sept.	25, 1872	2.07	1	48	1.15
Baltimore, Md.	June	4, 1891	1.15	1	00	1.15
Washington, D. C....	June	21, 1877	1.64	1	26	1.14
Fallston, Md.	August	12, 1893	2.85	2	31	1.13
Baltimore, Md.	August	12, 1875	1.41	1	15	1.13
Baltimore, Md.	July	31, 1884	1.40	1	15	1.12
Baltimore, Md.	August	5, 1888	1.12	1	00	1.12
Fort McHenry, Md..	May	28, 1882	2.50	2	15	1.11
West Wash., D. C...	Dec.	24, 1891	1.09	1	00	1.09
Gambrill's, Md.	August	23, 1889	2.13	2	00	1.07
Washington, D. C....	October	23, 1876	1.89	1	47	1.06
Washington, D. C....	August	6, 1889	1.05	1	00	1.05
Baltimore, Md.	July	5, 1895	1.05	1	00	1.05
Washington, D. C....	October	4, 1877	2.05	2	00	1.03
Baltimore, Md.	August	8, 1888	1.03	1	00	1.03
Frederick, Md.	Sept. 13-14,	1892	4.07	4	00	1.02
Wood Lawn, Md. ...	August	18, 1875	2.00	2	00	1.00
Washington, D. C....	Nov.	24, 1884	1.00	1	00	1.00
Barren Crk. Spgs., Md.	May	20, 1889	1.00	1	00	1.00
Sunnyside, Md.	July	27, 1894	1.00	1	00	1.00
Washington, D. C....	July	1, 1884	1.95	2	03	0.95
Washington, D. C....	July	24, 1868	2.30	2	30	0.92
Washington, D. C....	October	4, 1877	2.49	3	00	0.83
Washington, D. C....	July	27, 1873	2.00	2	00	0.80
Washington, D. C....	August	29, 1875	2.30	3	25	0.67
Washington, D. C....	August	1, 1875	2.13	3	24	0.62

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APPENDIX III.

CAPACITY OF A FEW DRAINS AND THE PROBABLE
FUTURE RUN-OFF.

NOTE.—The capacities of some of the present drains, and the probable run-off from the territories respectively drained by them, have been computed as closely as possible, and the results are shown in the following table :

Number of Drain.	Location.	Size.	Area Sq. Feet.	Mean Radius.	Hydraulic Slope.	Present capacity in cu.ft.per sec., running full.	Number of acres drained.	Average Slope of Territory per 1000.	Character of Territory.	Eventual Run-off in cu. ft. per sec.
12	Penn Street and Lombard,	16' x 8'	104.73	2.52	0.95%	1876	320	23	Well built up, Business,	519 658
25	Pulaski Street and Franklin,	11' diam.	95.03	2.75	0.8%	1646	500	37	Sparsely built up, Well built up,	589 824
5	Calhoun Street and Mosher,	4' 6" diam.	15.90	1.125	2.0%	240	121	23	Sparsely built up, Well built up,	173 240
57	Lovegrove Alley and 20th Street,	6½' x 6'	28.27	1.57	1.36%	469	212	25	Well built up,	380
1	Cor. Carey and Herkimer,	17' x10'	121.42	2.92	0.65%	1979	593	25	Well built up,	865
1	Cor. Bush and Columbia,	19' x10'	135.39	3.00	0.50%	1973	847	25	Well built up,	1150
48	Broadway; cor. Lombard & Ann	3' 0"	7.068	0.75	1.58%	70	68	24	Well built up,	113
	Cor. Ann & Gough,	3' 3"	8.295	0.81	1.8%	93	83	25	Well built up,	133
	Cor. Eastern Ave.,	4' 0"	12.566	1.00	1.0%	123	131	23	Well built up,	255

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APPENDIX IV.

ESTIMATES OF COST.

A.—SUMMARIES FOR CONSTRUCTION.

1. Dilution Project :

a. All interceptors, pumping station, force main and the outfall sewer are sufficient for the sewage from one million persons; the

outlet pipe and pumping machinery are for about one-third of the same.

Pumping station at Front and Lombard streets	\$69,880.00
Pumping machinery	90,000.00
Boilers	6,400.00
Force main, 48" cast-iron pipe, 3,630 feet	39,950.00
High level interceptor	1,029,760.00
Low level interceptor	413,110.00
Locust Point interceptor	165,909.00
York street interceptor	42,598.00
Outfall sewer, City line to Chesapeake Bay	1,722,560.00
Outlet pipe in the Bay, 5,000 lineal feet	300,000.00
Total	<u>\$3,880,167.00</u>

b. All works are for one million persons.

Pumping station at Front and Lombard streets	\$69,880.00
Pumping machinery	135,000.00
Boilers	10,400.00
Force mains, 48" cast-iron pipe, 3,630 feet	39,950.00
High level interceptor	1,029,760.00
Low level interceptor	413,110.00
Locust Point interceptor	165,909.00
York street interceptor	42,598.00
Outfall sewer, City line to Chesapeake Bay	1,722,560.00
Two outlet pipes, each 5,000 feet long	600,000.00
Two outlet pipes, extended to 18 feet of water, 7,500 feet.....	900,000.00
Total	<u>\$5,129,167.00</u>

2. *Precipitation Project.*

a. All interceptors, pumping station, force main and the outfall sewer are sufficient for the sewage from one million persons; the

tanks, buildings and all machinery are for about one-third of the same.

Pumping station at Front and Lombard streets	\$69,880.00
Pumping machinery	90,000.00
Boilers	6,400.00
Force main, 48" cast-iron pipe, 3,630 feet	39,950.00
High level interceptor	1,029,760.00
Low level interceptor	413,110.00
Locust Point interceptor	165,909.00
York street interceptor	42,598.00
Outfall sewer, City line to tanks.	383,787.00
Precipitation tanks	630,510.00
Building and machinery	90,096.00
Total	<u>\$2,962,000.00</u>

b. All works are for one million persons.

Pumping station at Front and Lombard streets	\$69,880.00
Pumping machinery	135,000.00
Boilers	10,400.00
Force main, 48" cast-iron pipe, 3,630 feet	39,950.00
High level interceptor	1,029,760.00
Low level interceptor	413,110.00
Locust Point interceptor	165,909.00
York street interceptor	42,598.00
Outfall sewer, City line to tanks,	383,787.00
Precipitation tanks	1,682,510.00
Buildings and machinery	280,096.00
Outfall sewer, from tanks to Chesapeake Bay	1,250,000.00
Total	<u>\$5,503,000.00</u>

3. Filtration Project.

a. All interceptors, the pumping station and force mains are for the sewage of one million persons; the tanks and machinery are for temporary precipitation.

Pumping station and accessories	\$262,000.00	
Pumping machinery: three 30,- 000,000 gallon pumps	135,000.00	
Boilers, two 500 horse-power ..	16,000.00	
Force mains, pumping station to tanks	816,450.00	
Interceptors, as per <i>b</i>	1,410,474.00	
Precipitation tanks	288,992.00	
Buildings and machinery	90,096.00	
Total		\$3,019,012.00

b. All interceptors and the pumping station are sufficient for the sewage from one million persons; the filtration fields, discharge mains and pumping machinery are for about one-third of the same.

Land for filtration, 1,884 acres..	\$94,200.00	
Preparing 1,216 acres	1,262,203.00	
Buildings and utensils for 6 stations	40,000.00	
Force and gravity mains	1,445,770.00	
Tunnel, 8,000 lineal feet	811,360.00	
Pumping station and accessories	262,000.00	
Pumping machinery	383,000.00	
Boilers	32,000.00	
Eastern low level interceptor..	570,078.00	
Western low level interceptor..	129,834.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Eastern high level interceptor.	299,490.00	
Western high level interceptor.	202,565.00	
Total		\$5,741,007.00

c. All works are for one million persons.

Land for filtration, 5,384 acres.	\$269,200.00	
Preparing 3,766 acres	3,416,773.00	
Buildings and utensils for 18 stations	120,000.00	
Force and gravity mains	4,614,984.00	
Tunnel, 8,000 lineal feet	811,360.00	
Tunnel, 3,400 lineal feet	429,012.00	
Pumping station and accessories	262,000.00	
Carried forward	\$9,923,329.00	

Brought forward	\$9,923,329.00
Pumping machinery	758,000.00
Boilers	80,000.00
Eastern low level interceptor...	570,078.00
Western low level interceptor..	129,834.00
Locust Point interceptor	165,909.00
York street interceptor	42,598.00
Eastern high level interceptor..	299,490.00
Western high level interceptor..	202,565.00
Total	<u>\$12,171,803.00</u>

B.—SUMMARIES FOR ANNUAL MAINTENANCE, INTEREST AND
RENEWALS.

1. *Dilution Project.*

a. For immediate needs.

Interest on first cost, \$3,880,167.00 @ 4%	\$155,206.68
Depreciation and renewals:	
On whole cost, \$3,880,167.00 @ 1%	\$38,801.67
On force main, \$39,950.00 @ 1% additional ...	399.50
On pumping machinery, \$90,000 @ 2% addi- tional	1,800.00
On boilers, \$6,400.00 @ 4% additional	256.00
On siphons, \$101,919.00 @ 1% additional	1,019.19
	<u>42,276.36</u>

Cost of pumping:

Per day:

Chief engineer	\$3.00
Assistant engineer	2.50
Firemen, 2 @ \$1.75	3.50
Helpers, 2 @ \$1.50	3.00
	<u>\$12.00</u>
Oil and waste	1.20
Coal, 3.5 net tons, @ \$3.00	10.50
	<u>\$23.70</u>
10%	2.37
	<u>\$26.07</u>

Carried forward\$197,483.04

Brought forward	\$197,483.04
365 days @ \$26.07	9,515.55
Maintenance of interceptors, 4 men @ \$625.00.....	2,500.00
Maintenance of outfall, 4 men @ 625.00.....	2,500.00
Dredging at outfall, 1,000 cu. yds., .20.....	200.00
Superintendent	1,500.00
Total	<u>\$213,698.59</u>

b. For one million persons.

Interest on first cost, \$5,129,167.00 @ 4%.....	\$205,166.68
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Depreciation and renewals:

On whole cost, \$5,129,167.00 @ 1%.....	\$51,291.67
On force main, \$39,950.00 @ 1% additional...	399.50
On pumping machinery, \$135,000.00 @ 2% additional	2,700.00
On boilers, \$10,400.00 @ 4% additional.....	416.00
On siphons, \$101,919.00 @ 1%.....	1,019.19
	<u>\$55,826.36</u>

Cost of pumping:

Per day:

Chief engineer	\$3.00
Assistants, 3 @ \$2.50.....	7.50
Firemen, 4 @ \$1.75.....	7.00
Helpers, 3 @ \$1.50.....	4.50
	<u>\$22.00</u>
Oil and waste	2.20
Coal, 10.5 net tons, @ \$3.00.....	31.50
	<u>\$55.70</u>
10%	5.57
	<u>\$61.27</u>

365 days @ \$61.27	22,363.55
Maintenance of interceptors	2,500.00
Maintenance of outfall	2,500.00
Dredging at outfall, 3,000 cu. yds. @ 20 cts.....	600.00
Superintendent	1,500.00
Total	<u>\$290,456.59</u>

2. *Precipitation Project.**a. For immediate needs.*

Interest on first cost, \$2,962,000.00 @ 4%.....\$118,480.00

Depreciation and renewals:

On whole cost, \$2,962,000.00 @ 1%.....\$29,620.00

On force main, \$39,950.00 @ 1% additional... 399.50

On pumping machinery, \$90,000.00 @ 2%
additional 1,800.00

On boilers, \$6,400.00 @ 4% additional..... 256.00

On siphons, \$14,994.00 @ 1% additional..... 149.94

On disposal works, \$720,606.00 @ 5-10 of 1%
additional 3,603.03

35,828.47

Cost of pumping, same as dilution project 9,515.55

Maintenance of interceptors, 4 men @ \$625.00..... 2,500.00

Maintenance of disposal works; provide for 333,000
people @ 35 cts..... 116,550.00

Superintendent 1,500.00

Total\$284,374.02*b. For one million persons.*

Interest on first cost, \$5,503,000.00 @ 4%.....\$220,120.00

Depreciations and renewals:

On whole cost, \$5,503,000.00 @ 1%.....\$55,030.00

On force main, \$39,950.00 @ 1% additional... 399.50

On pumping machinery, \$135,000.00 @ 2%
additional 2,700.00

On boilers, \$10,400.00 @ 4% additional..... 416.00

On siphons, \$14,994.00 @ 1% additional..... 149.94

On disposal works, \$1,962,606.00, $\frac{1}{2}$ of 1% addi-
tional 9,813.03

68,508.47

Cost of pumping, same as dilution project 22,363.55

Maintenance of interceptors 2,500.00

Maintenance of disposal works, provide for 1,000,000
persons @ 35 cts..... 350,000.00

Superintendent 1,500.00

Total\$664,992.02

3. *Filtration Project.*

a. For immediate needs, with temporary precipitation.

Interest on first cost, \$3,019,012.00 @ 4%.....\$120,760.48

Depreciation and renewals:

On whole cost, \$3,019,012.00 @ 1%.....	\$30,190.12	
On discharge mains, \$816,450.00 @ 1% addi-		
tional	8,164.50	
On pumping machinery, \$135,000.00 @ 2%		
additional	2,700.00	
On boilers, \$16,000.00 @ 4% additional.....	640.00	
On siphons, \$139,803.00 @ 1% additional.....	1,398.03	
On disposal works, \$379,088.00 @ 5-10 of 1%		
additional	1,895.44	
		44,988.09
		\$165,748.57

Cost of pumping:

Per day:

Chief engineer	\$3.00	
Assistants, 3 @ \$2.50.....	7.50	
Firemen, 4 @ \$1.75.....	7.00	
Helpers, 2 @ \$1.50.....	3.00	
		\$20.50
Oil and waste	2.00	
Coal, 5 net tons, @ \$3.00.....	15.00	
		\$37.50
10%	3.75	
		\$41.25
365 days @ \$41.25		15,056.25
Maintenance of interceptors		2,500.00
Maintenance of disposal works, providing for 333,000		
people, @ 35 cts.....		116,550.00
Superintendent		1,500.00
Total		
		\$301,354.82

b. For immediate needs, with filtration at Glen Burnie.

Interest on first cost, \$5,741,007.00 @ 4%.....\$229,640.28

Depreciation and renewals:

On whole cost, \$5,741,007.00 @ 1%.....	\$57,410.07	
Carried forward	\$57,410.07	
		\$229,640.28

Brought forward	\$57,410.07	\$229,640.28
On discharge mains and tunnel, \$2,257,130.00		
@ 1% additional	22,571.30	
On pumping machinery, \$383,000.00 @ 2%		
additional	7,660.00	
On boilers, \$32,000.00 @ 4% additional.....	1,280.00	
On siphons, \$139,803.00 @ 1% additional.....	1,398.03	
		90,319.40

Cost of pumping:

Per day:

Chief engineer	\$3.00
Assistants, 3 @ \$2.50.....	7.50
Firemen, 4 @ \$1.75.....	7.00
Helpers, 2 @ \$1.50.....	3.00
	\$20.50
Oil and waste	2.00
Coal, 17 net tons @ \$3.00.....	51.00
	\$73.50
10%	7.35
	\$80.85

365 days @ \$80.85	29,510.25
Maintenance of interceptors	2,500.00
Maintenance of filtration fields and discharge mains....	53,250.00
Superintendent	1,500.00

Deductions: \$406,719.93

Sale of crops is assumed to offset taxes and to repay:

Interest on cost of filtration fields, \$94,200.00	
@ 4%	\$3,768.00
Insurance on buildings and tools, \$40,000.00	
@ $\frac{1}{2}$ of 1%.....	200.00
	3,968.00
Total	
	\$402,751.93

c. For one million persons.

Interest on first cost, \$12,171,803.00 @ 4%.....\$486,872.12

Depreciation and renewals:

On whole cost, \$12,171,803.00 @ 1%.....	\$121,718.03
Carried forward	\$121,718.03
	\$486,872.12

Brought forward	\$121,718.03	\$486,872.12
Discharge mains and tunnels, \$5,855,356.00		
@ 1% additional	58,553.56	
On pumping machinery, \$758,000.00 @ 2%		
additional	15,160.00	
On boilers, \$80,000.00 @ 4% additional.....	3,200.00	
Siphons, \$139,803.00 @ 1% additional.....	1,398.03	
		200,029.62

Cost of pumping:

Per day:

Chief engineer	\$ 3.00	
Assistants, 7 @ \$2.50.....	17.50	
Firemen, 10 @ \$1.75.....	17.50	
Helpers, 4 @ \$1.50.....	6.00	
	\$ 44.00	
Oil and waste	4.00	
Coal, 58 net tons, @ \$3.00.....	174.00	
	\$222.00	
10%	22.00	
	\$244.00	
365 days @ \$244.00.....		89,060.00
Maintenance of interceptors		2,500.00
Maintenance of filtration fields and discharge mains,		
300 men @ \$470.00.....	\$141,000.00	
3 men @ 650.00.....	1,950.00	
		142,950.00
Superintendents, 2 @ \$1,500.00		3,000.00
		\$924,411.74

Deductions:

Sale of crops is assumed to offset taxes and to repay:

Interest on cost of filtration fields, \$269,200.00		
at 4%	\$10,768.00	
Insurance on buildings and tools, \$120,000.00		
@ $\frac{1}{2}$ of 1%.....	600.00	
		11,368.00
Total		\$913,043.74

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APPENDIX V.

LIST OF PLANS ACCOMPANYING REPORT.

- Plate A: Map showing Sewerage Districts, Intercepting Sewers, and Main District Sewers, for Dilution Project.
- Plate B: Map showing location of Main Outfall Sewer; also location of Precipitation Tanks.
- Plate C: Profiles and Sections of Outfall Sewer, also Plan, Profile and Section of Siphon under Bear Creek.
- Plate D: Plan of Settling Basin, Gate House and Outfall.
- Plate E: Plan of Precipitation Tanks.
- Plate F: Plan of Pumping Station for Dilution Project.
- Plate G: Map showing Sewerage Districts, Intercepting Sewers, and Main District Sewers, for Filtration Project.
- Plate H: Map showing Filtration Fields at Glen Burnie.
- Plate I: Plan and Profile of Discharge Mains; also Sections of Tunnel and River Crossing.
- Plate J: Sections of Intercepting Sewers and Siphons.
- Plate K: Profile of Intercepting Sewers.
- Plate L: Plan of Pumping Station for Filtration Project.
- Plate M: General Map, showing Outlines of Filtration Project.
- Plate N: Rainfall Diagram.
- Plate O: Method of Construction of Filtration Beds.

APPENDIX D

REPORT OF GENERAL WM. P. CRAIGHILL

APPENDIX D.

BALTIMORE, *July 20, 1897.*

TO THE SEWERAGE COMMISSION OF THE CITY OF BALTIMORE.

Gentlemen:—In accordance with your invitation of April 17th, I have had under careful consideration certain questions, suggested by you, relative to the disposal of the sewage of Baltimore by its discharge into the waters of Chesapeake Bay.

That some proper and sufficient method of sewage-disposal has long been a matter of urgent need for such a great and growing city as Baltimore will be readily admitted by every thinking man who is acquainted with existing conditions which are becoming more pressing every day. These conditions have been fully discussed by others, and I refrain from saying anything in reference to them.

I have had the opportunity, through your courtesy, of examining the elaborate report made to your Commission by Messrs. Rudolph Hering and Samuel M. Gray under date of November, 1896. Baltimore is fortunate in having had the services of such experts on the treatment of sewage-disposal and in being able to take advantage of the experience gained in past years in many other cities in this country and in Europe in that matter.

Much valuable information is also to be found in the able report of August, 1881, made by one of your own citizens, Mr. Chas. H. Latrobe. His conclusion then was that the "outfall main" or conduit should be carried to the open water of the bay.

Hering and Gray remark that "there are several methods, according to which, sewage can be safely and properly disposed of; namely, by a dilution in large bodies of water, by precipitation and separation from the sewage of a large portion of the organic matter, and by filtration of the sewage through porous soil." The applicability of all these methods, Dilution, Precipitation and Filtration, to the case of the City of Baltimore, is very carefully and fully discussed by these gentlemen, and in comparing they specify them as "the discharge of crude sewage into the deep waters of the

Chesapeake Bay, the discharge of clarified sewage into the Patapsco River and eventually into Chesapeake Bay near the shore, and the purification by filtration in Anne Arundel county." The whole subject is considered from the point of view of existing conditions and what may reasonably be expected when Baltimore will have a population of a million of people.

After presenting in detail the advantages and disadvantages of the three methods, Dilution, Precipitation and Filtration, with estimates of cost, these gentlemen strongly advocate a disposal of the sewage by Filtration in Anne Arundel county at a location where the natural conditions are highly favorable for the application of that method.

The summary of estimates of cost of the three methods given by Hering and Gray is as follows:

Project.	Construction, total cost.	Maintenance, interest and renew- als per annum.
1. <i>Dilution.</i>		
a. For immediate needs.	\$3,880,167	\$213,700
b. For one million persons.	5,129,167	290,460
2. <i>Precipitation.</i>		
a. For immediate needs.	2,962,000	284,400
b. For one million persons.	5,503,000	665,000
3. <i>Filtration.</i>		
For immediate needs with		
a. Temporary precipitation	3,019,012	301,355
b. Filtration at Glen Burnie. . .	5,741,007	402,752
c. For one million persons.	12,171,803	913,044

The experts state that "the final disposal of the sewage required the consideration of three methods, which are all applicable and according to any of which the sewage can be disposed of without offense."

In view of the fact here stated, which may be accepted on such high authority, a question for those who will pay for the sewage-disposal very naturally arises; if the method of Dilution can be used satisfactorily and without offense by Baltimore at a cost less than half that of Filtration, why should not that method be adopted?

The experts say, that "to dispose of sewage by dilution means to discharge it into running water in a suitable proportion so that no putrefaction will take place, and that the oxygen contained in the water will gradually decompose the organic matter of the sewage and convert it into harmless compounds. When sewage is thus diluted it gives no offense." This method has been fully examined by your experts, as appears from the following statements in their report: "In order to show the probable effect of discharging sewage into the Patapsco River at different points under the least favorable conditions, the necessary calculations were made. These conditions occur when the dry weather flow enters the river from its drainage area and therefore contributes the least amount of water to dilute the sewage." And they state further, as follows: "Could the sewage of Baltimore be discharged into the current of the waters of the Chesapeake Bay, it is safe to assume from what was said above that, at the lowest figure applied to non-tidal streams, the sewage of about two and a quarter million people might thus be disposed of at the most unfavorable time." They say also, "a disposal of the sewage of Baltimore by dilution therefore would mean nothing less than the building of a sewer to near North Point and of discharging its contents into the current of the Chesapeake Bay. No point nearer the city, and no smaller body of water, such as Back River, would prevent dissatisfaction." In their comparison of the several methods of sewage-disposal, Hering and Gray say: "When we consider that a discharge of crude sewage into Chesapeake Bay does not at once effectually dispose of it, but allows it to oscillate with the tides in the navigable waters and over oyster beds before it is thoroughly dispersed * * *"

In view of the objections just given to the disposal of the sewage through an outfall near North Point, it seemed expedient to your Commission to give further and very careful consideration to them before submitting a recommendation to the Mayor and City Council of the city. Accordingly it was decided to make additional observations of the direction of the currents at all stages of the tide in the vicinity of the point indicated by Hering and Gray for the mouth of the outfall sewer.

Fortunately for the object in view a re-survey of the Chesapeake Bay was about to be undertaken under the supervision of the Superintendent of the U. S. Coast and Geodetic Survey, a part of the work consisting of observations of the directions and velocities

of the currents near North Point and elsewhere in the adjacent parts of the Bay. The Superintendent of the Coast Survey very courteously agreed that all results of this special kind which could be useful in the line of investigation of the Sewerage Commission could be at once placed at the disposal of the Commission. Lieut. Tillman, U. S. Navy, the officer in charge, has evinced a great interest in the matter, and his observations and results have been of great value. They were all made from a point about two and a quarter miles northeast of North Point and about one mile from the shore.

A study of the observations by Lieut. Tillman led to the conclusion that, if the outfall were at the point indicated off North Point, there would be danger at certain stages of the tide of a movement of some of the sewage towards Sparrow's Point and the shores near North Point. And here it may be said, that even in that event, the portion of the discharged sewage thus lingering would probably have been long enough in the water of the Bay to be thoroughly diluted and made inoffensive.

It was decided, however, from abundant caution, to consider other points for the outlet, some distance to the east and north of North Point, and a special party was organized to make additional current observations under the immediate direction of Mr. Kennedy, acting under the supervision of Mr. Allen, Principal Assistant Engineer of the Commission. Accordingly, a large number of floats were set adrift at all stages of the tide from points east of the Rear Light of the ship-channel and approximately 0.92, 1.42, 1.92, 2.42, 2.92, and 3.42 miles from the same.

There was a tendency also in some of the Kennedy floats to drift at times towards and hang around the western shore near and north of North Point, when the floats started from points less than two miles from the shore, as there is a manifest eddy which sweeps them in that direction on the flood tide, but this tendency is less as the point of setting the float loose is farther from the shore; moreover, as remarked before, during the observed intervals elapsing after the times of starting such floats and their approach to the shore, there would be ample opportunity for the dilution of any sewage taking the same course by admixture with the large volume of water with which it would be in contact in its movements from the outlet. The conditions at and near the mouth of the Patapsco River are far different from those under the eyes of the citizens of Baltimore in the Basin in the city, and at Spring Garden,

where one of the largest sewers empties. There is no fresh water entering the upper part of the Basin except what flows from the surface of the streets during rains, and that is much polluted by what it gathers on its way. Spring Garden is not in a much better condition. At the mouth of the Patapsco there is not only the vertical oscillation due to the rise and fall of the tides, but there is the constant horizontal movement due to the currents generated by the tides and the great outpour of fresh water from the Susquehanna and other rivers, so that sewage discharged into the Bay two miles from the shore commences to be diluted at once, and becomes more and more so in an increasing ratio the longer it is out of the sewer and the further it goes from its mouth, until finally, after passing the mouth of the Patapsco in its movement down the Bay, or even sooner, its offensiveness will have entirely disappeared.

If sewage were discharged only during ebb tide, the tendency to hang around the mouth of the Patapsco would be much less, and it might for that reason be found expedient to arrange basins on shore to receive and hold the sewage during the period of flood tide and discharge it only upon the ebb, but I do not believe that will be ever necessary. A favorable circumstance in this connection is found in the fact that about one-half of the sewage of a city is discharged in eight hours, whereas the ebb tide is flowing out at least twelve of the twenty-four.

It is understood that your Commission proposes to discuss the possible effect upon the oyster beds in the portion of the Bay where sewage might be found in the event of the adoption of the Dilution plan. I may, however, remark that in my opinion that question is not a serious one, as few, if any, valuable beds of oysters would be injured by the diluted sewage under any circumstances, and there would be no great hardship even if, to a moderate extent, there should be such an injury, inasmuch as in any case of a work of vast benefit and importance to a great community, like the population of one of the largest cities of our country, there is always more or less injury caused to individuals or to a small part of that community. It would be easy for the City of Baltimore to secure for itself from the Legislature of the State complete control of any beds of oysters at all endangered by its sewage and thus prevent their use.

One of the most formidable objections in many cases to the dilution method of disposing of sewage is the danger to other communities at lower points of the stream or other body of water

used for the purpose. This objection does not exist in the case under consideration. There is no large, or even a small, community to be disagreeably affected by the plan now proposed, nor is such a community likely ever to appear within a long distance from the point recommended for the outfall.

The small volume of available water is also a great objection to the use of the dilution method in many localities. This objection does not exist in the present case. The Bay is seven miles wide where the sewage is proposed to be emptied into it. The depth varies from three feet at the Rear Channel Light to 25 or 30 feet not far from the proposed outfall. The great river Susquehanna is constantly pouring an immense volume of fresh water into the Bay near Havre de Grace, all of which must flow past the line on which the outfall of the sewage of Baltimore is proposed to be located. At a low stage of the river, though not the lowest, there is a discharge above Port Deposit of 35,000 cubic feet a second, which in 24 hours would amount to more than 3,000 millions of cubic feet. There are only about 20,000,000 cubic feet of sewage in 24 hours to be treated. With a rise of three feet above low water the discharge at the same place was 100,000 cubic feet per second, which would give 9,000 millions of cubic feet in 24 hours. A freshet of 17 feet at Port Deposit would give a discharge of 900,000 cubic feet a second, which would be 75,000 millions of cubic feet in 24 hours. This last, however, would be a rare and exceptional case.

The figures above given are derived from a U. S. survey of 1894 and 1895, at a point near Port Deposit and just above tidal influence. They are somewhat larger than those used by Hering and Gray, derived from points higher up the river, but their figures are quite large enough for all the needs of the present case, and it is always best in discussions like this to view the situation from the most unfavorable standpoint.

A high freshet in the Susquehanna, one of the greatest rivers on the Atlantic coast, is an annual occurrence and would produce an enormous cleansing effect on the portion of the Bay off the mouth of the Patapsco, should any such cleansing be needed. The same can be said of the effect of the scouring caused by the large masses of ice which pass out of the Susquehanna every winter.

But there is no good reason to expect any such need to arise when it is remembered that the sewage which would flow into the Bay would be freed of all bodies which could not pass through a

hole an inch on a side, as it is proposed to have screens to catch all such matter which would be taken out and burned. All matter capable of solution would be comminuted before reaching the point of outflow. Thus, what would reach Chesapeake Bay would be little more than polluted water, not very offensive in any way, even to the nostrils of persons near at hand. This is the actual experience near Boston and other places where the dilution method properly arranged is applied with success.

To the outflow from the Susquehanna above Port Deposit is also to be added, as available for the dilution of the sewage from Baltimore, the water from Principio, Northeast, Elk and Sassafras Rivers from the eastern shore north of the Patapsco, and from the Bush, Gunpowder and Back Rivers on the west shore. The water from the watersheds of the Patapsco and its tributaries should also be added to the volume available for the dilution of the sewage of Baltimore, as both must pass together down the Bay below the mouth of the Patapsco.

It is well here to call attention to the following extract from the River and Harbor Act of August 17th, 1894, which is very stringent in its prohibitions. Section 6. "That it shall not be lawful to place, discharge, or deposit, by any process or in any manner, ballast, refuse, dirt, ashes, cinders, mud, sand, dredgings, sludge, acid, or any other matter of any kind other than that flowing from streets, sewers, and passing therefrom in a liquid state, in the waters of any harbor or river of the United States, for the improvement of which money has been appropriated by Congress, elsewhere than within the limits defined and permitted by the Secretary of War; any and every such act is made a misdemeanor, and every person knowingly engaged in or who shall knowingly aid, abet, authorize, or instigate a violation of this Section shall, upon conviction, be punishable by fine or imprisonment, or both; such fine to be not less than two hundred and fifty dollars, nor more than twenty-five hundred dollars, and the imprisonment to be not less than thirty days nor more than one year, either or both united, as the judge before whom conviction is obtained shall decide, one-half of said fine to be paid to the person or persons giving information which shall lead to the conviction of this misdemeanor." It will be observed that just such matter as is to be treated by the dilution method of disposing of the sewage of Baltimore is excepted from the operation of this law.

Some thirty years ago a thorough study was made of the currents

in the Bay north and south of the mouth of the Patapsco River when the subject of the new location of the ship-channel was under consideration. Experience has demonstrated that the conclusions then drawn were sound and correct. Conditions have not materially changed so far as the currents are concerned. These currents are due to three causes: the outflow of fresh water from the Susquehanna and Patapsco and their tributaries and other streams emptying into the Bay south of Havre de Grace, the tides and the winds. The influence of the tides on these currents is much less in the upper part of Chesapeake Bay than in many other localities where the vertical movement is very much greater. The influence of the wind is not great, except in storms which are exceptional and never of long duration.

A point of the first importance is the fact beyond question that, however the winds may blow and the tide may rise and fall, the great flow of fresh water from the Susquehanna, Patapsco and other streams never ceases and is always in the main downward and outward until it is lost in the ocean. And this downward movement is reinforced by the ebb tide during at least 12 of every 24 hours. The force which may be depended upon for the removal of the sewage of Baltimore, if poured into the Bay at a properly selected point, is therefore far greater than that which would tend to hold the sewage or push it up-stream for a short time under certain conditions of tide and wind. This is the force which was relied upon for the maintenance of the increased depth to be given in the new ship-channel, and the confidence in it to accomplish the desired result, which was at first a theory based upon study and observation, has been justified by actual results. Existing facts speak for themselves.

The volume of the flow of the Susquehanna and its tributaries far exceeds that of the Patapsco. The resultant of these two forces when they meet near the mouth of the Patapsco is necessarily near the western shore, where the present channel was successfully located. The effect of this greater force of the Susquehanna flow, impinging upon the flow from the Patapsco, is to check the latter to a certain extent, and an eddy is formed, especially during the flood tide and when the wind is in certain directions, and thus a movement is caused like a reflex current which sweeps in a northeasterly direction along the western shore north of North Point until it is drawn again into the great down current of the Susquehanna farther eastward.

The observations of Lieut. Tillman near North Point and those of Mr. Kennedy farther northward and eastward, have emphasized the fact stated above in a most pointed way, and the diagrams of the movements of the floats made in your office by Mr. Allen, or under his supervision, show this reflex movement very graphically. They also show that if the point of discharge of the sewage be located sufficiently far from the western shore, not less than two miles, and sufficiently far north of North Point, it will be carried out into the main current from the Susquehanna and then southerly. There may be a little northerly movement in the southern course, but the general progress is southerly or toward the ocean.

While the conclusions from the observations of floats this year are interesting and in conformity to known conditions as to directions and velocities of currents, your Commission is aware that owing to bad weather and other untoward circumstances, they were not so extensive and complete as is desirable before a final location for the mouth of the outfall sewer.

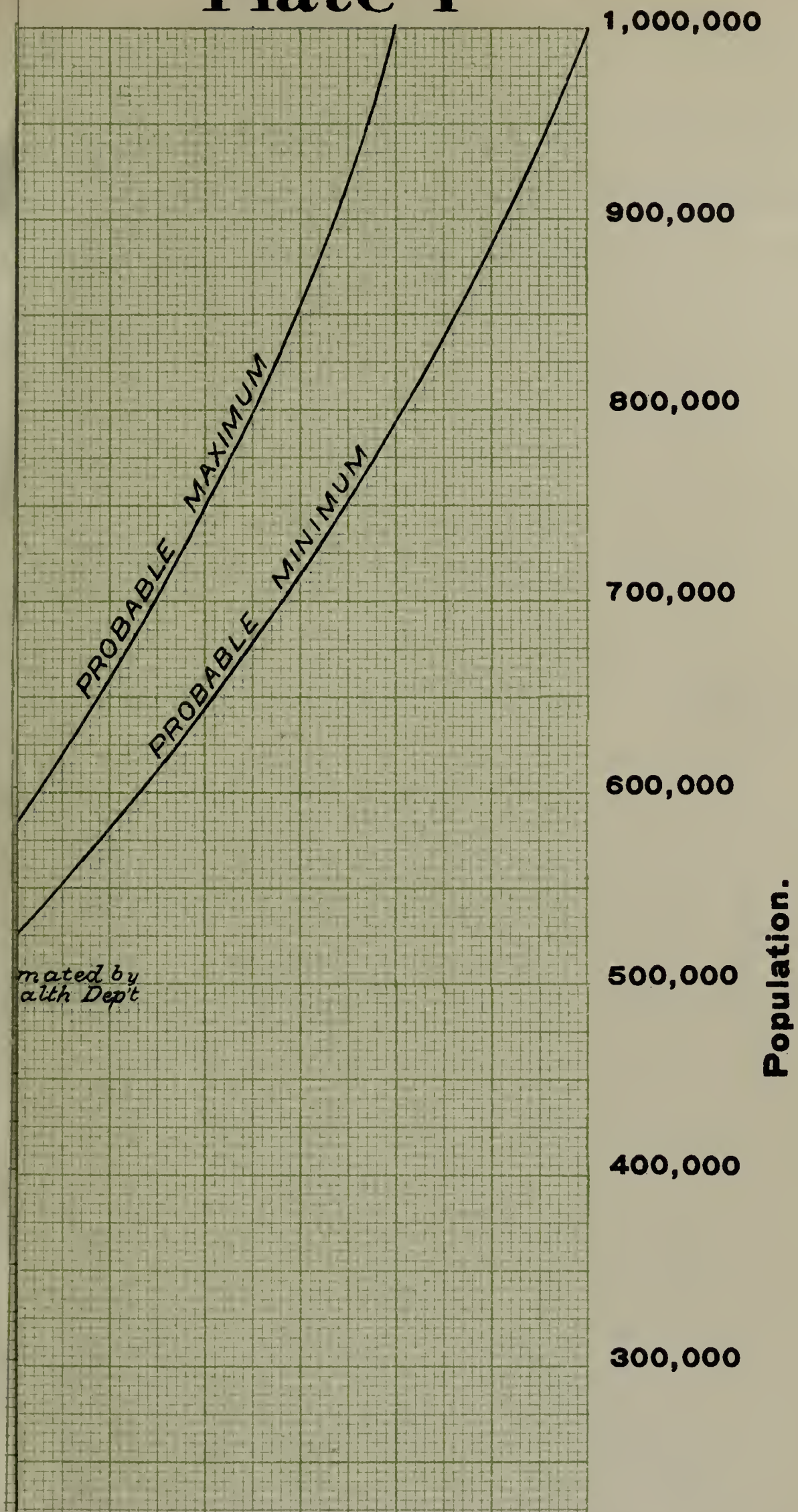
It is right to call attention here to the fact that the amount of the total daily sewage of Baltimore which is put on a very liberal estimate at 20,000,000 of cubic feet is only 1-150 of the ordinary daily low-stage outflow of the Susquehanna alone; there is thus an ample supply of water for all purposes of dilution and oxidation of the sewage.

In conclusion I have therefore to state that after a long observation and study of the currents of the Bay above and below the mouth of the Patapsco, and full and careful consideration of all the conditions and circumstances of the present case, it is my decided conviction that the dilution method of disposing of the sewage of Baltimore *may be* adopted with entire safety and without offense, provided the outlet of the sewer into the Bay be not farther south than a line eastward of the rear range of the ship-channel and not nearer the western shore than two miles; and the dilution method *should be* adopted as being far more economical, both in first cost and in maintenance, than the method of filtration. To determine precisely the best point for the outlet of the sewer into the Bay there should be additional observations made in connection with the detailed surveys, which should precede the definitive location of the system before placing the work under contract.

Very respectfully yours,

WM. P. CRAIGHILL.

Plate I



BALTIMORE SEWERAGE COMMISSION. DIAGRAM SHOWING POPULATION OF BALTIMORE, from Records of the U. S. Census and Baltimore Police Census. September 1897.

Note. Results according to U. S. Census shown thus ○
Results based upon Police Census shown thus ●
Police estimates subsequent to 1873 obtained by multiplying voting population
by the factor 4.42. The factor used for 1870 and 1873 not known.
The 21st and 22nd wards were annexed in 1890.

SEWERAGE COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

*Kenneth Allen,
Prin. Asst. Engr.
Sept. 7, 1897*

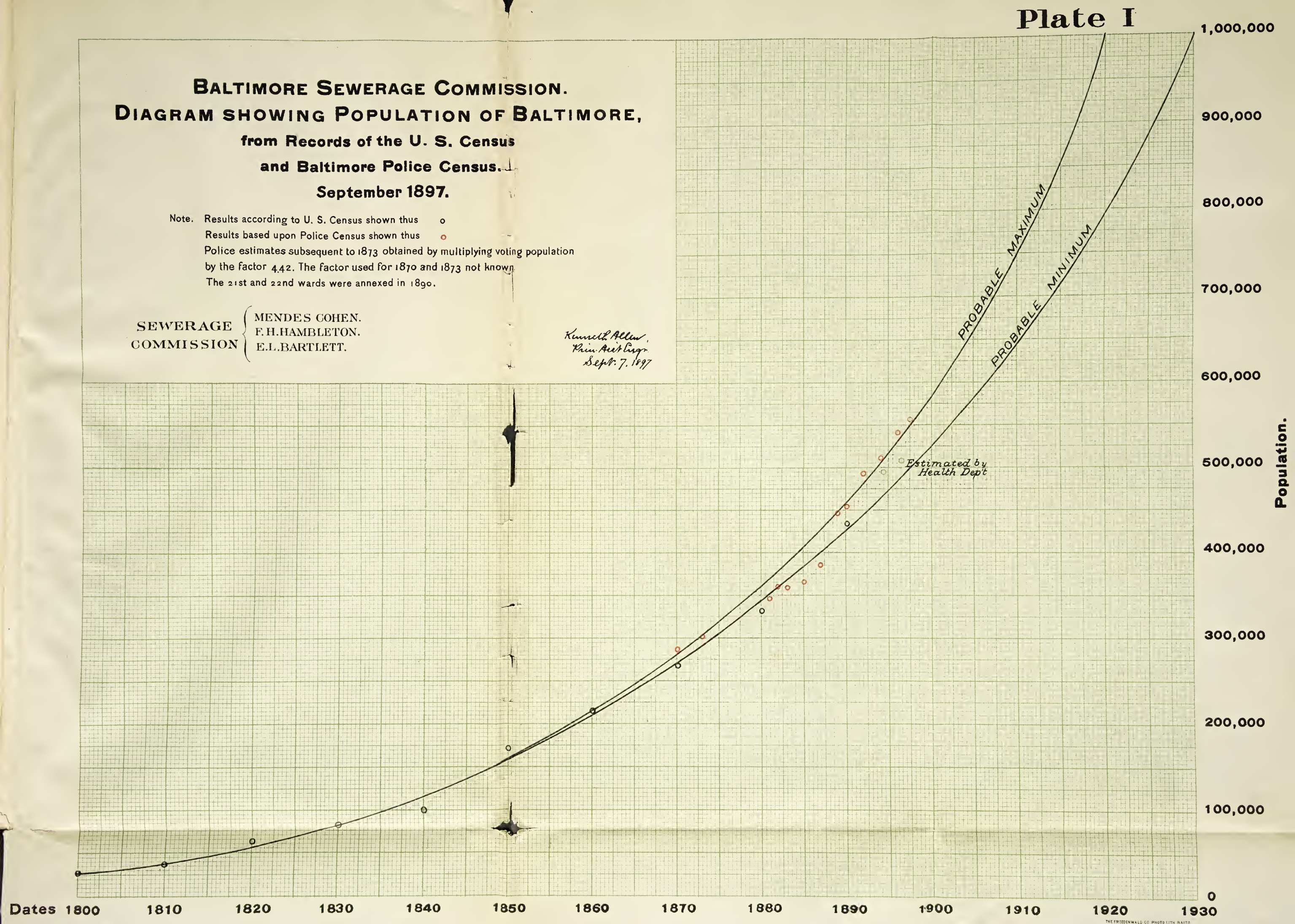
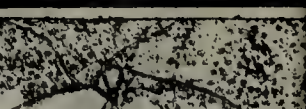


Plate II



39°20'
04"SEWERAGE
COMMISSIONMENDES COHEN,
F.D. HAMBLETON,
E.J. BARTLETT.

NOTE

LETTERS A, B, C AND D REFER TO THE SEVERAL LOCATIONS OF OUTLET FOR THE CORRESPONDING PROJECT.

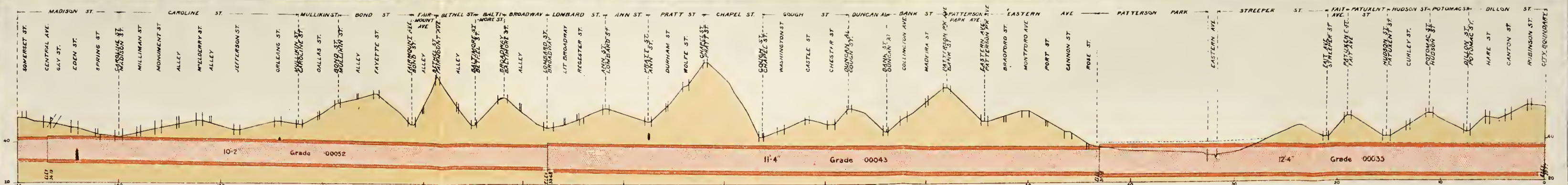
BALTIMORE



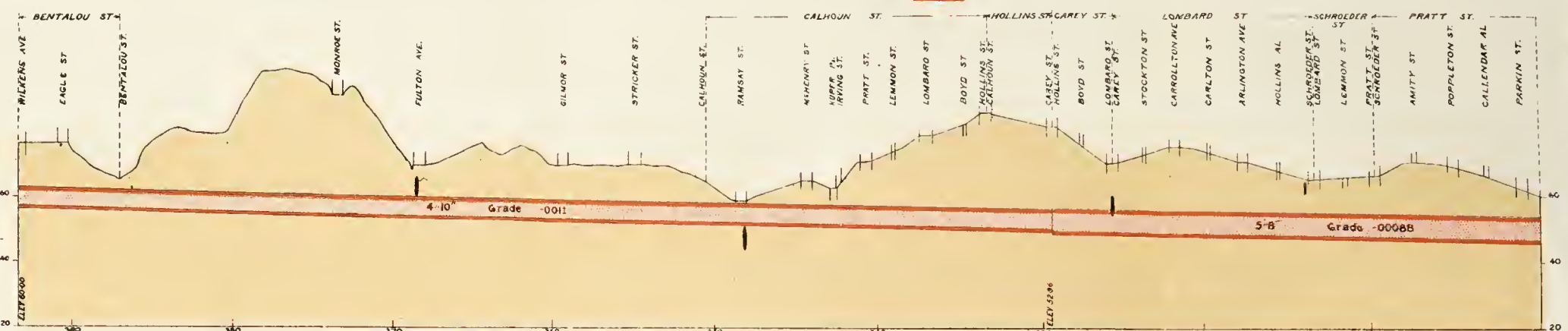
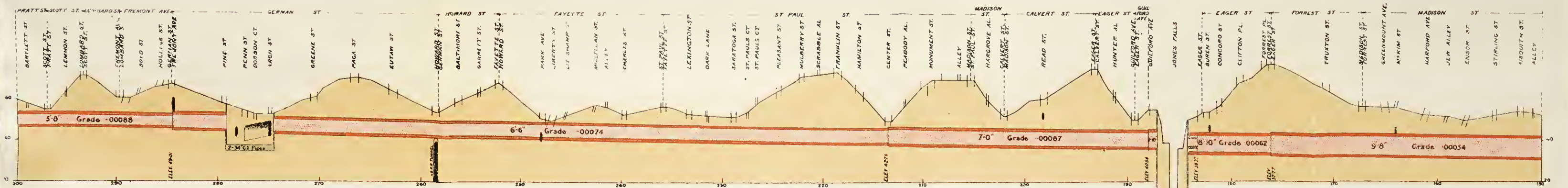
ANK ST.
MADEIRA ST.
PATTERSON PK. AVE



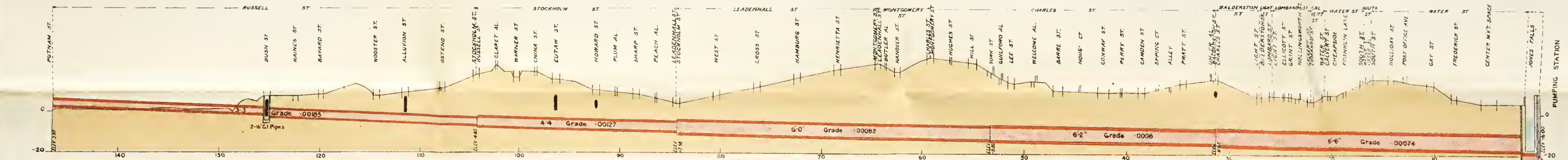
1923



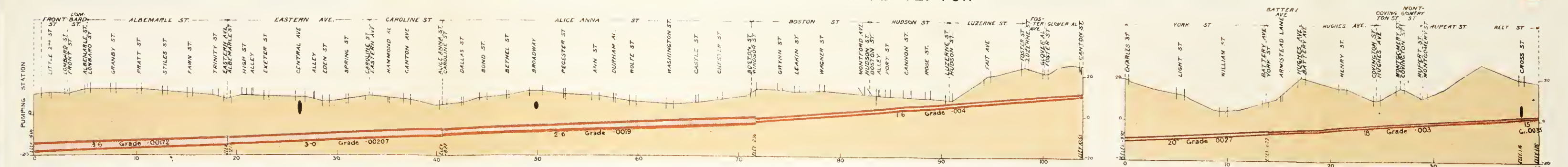
HIGH LEVEL INTERCEPTOR



WESTERN LOW LEVEL INTERCEPTOR



EASTERN LOW LEVEL INTERCEPTOR



LOCUST POINT INTERCEPTOR

YORK STREET INTERCEPTOR

Note: The interceptors are designed for a velocity of 4 feet per second running full but excepting the following, which have been modified to meet local conditions. High Level Interceptor 12 feet in diameter, Eastern Low Level Interceptor east of Caroline St and the York St, and Locust Point Interceptors.

SCALES
HORIZONTAL: 0 250 500 750 1000 FT.
VERTICAL: 0 10 20 30 40 50 FT.

DATUM MEAN LOW TIDE AT BALTIMORE.
ELEVATIONS OF SEWERS REFER TO CENTER LINE

Kenneth Allen
Principal Engineer
Jan. 15, 1897.

THE SEVENAGE COMMISSION

THE SEVENAGE COMMISSION
OF THE CITY OF LONDON
FOR THE YEAR 1871

NAME

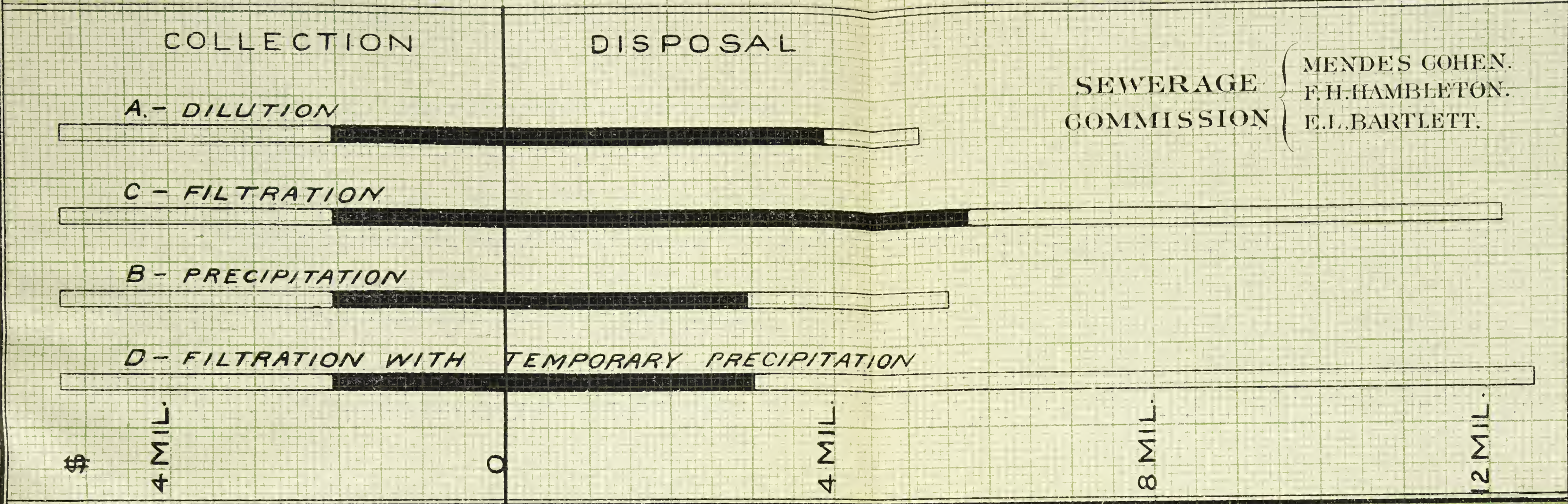
AGE

THE SEVENAGE COMMISSION

THE SEVENAGE COMMISSION
OF THE CITY OF LONDON
FOR THE YEAR 1871

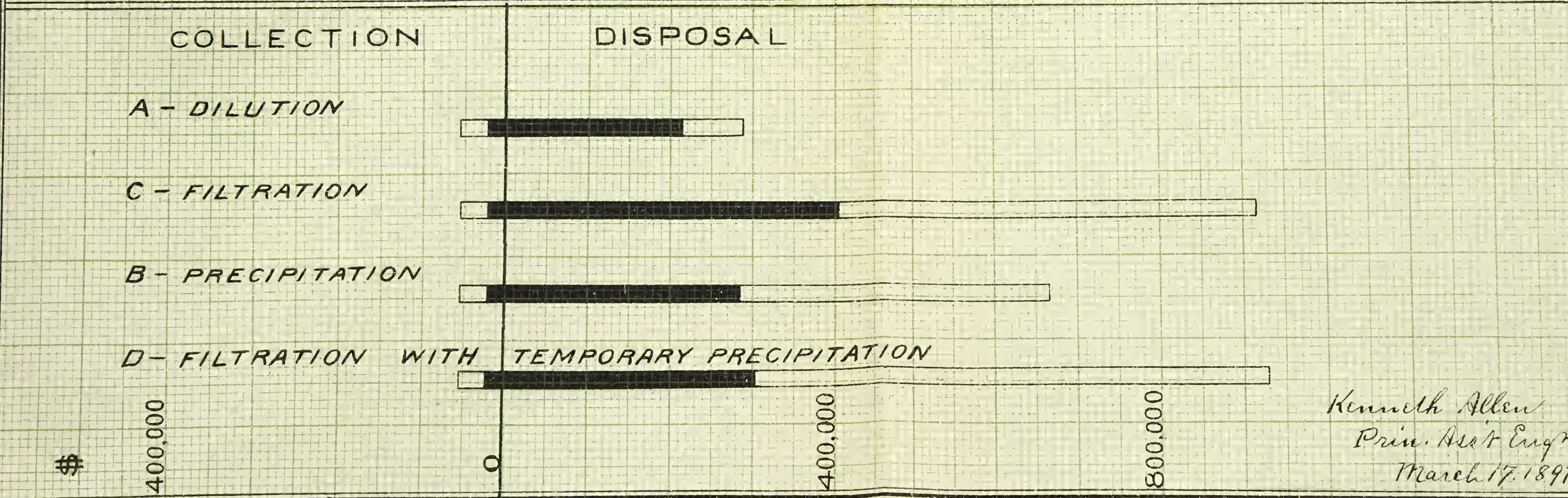
BALTIMORE SEWERAGE COMMISSION

COST OF CONSTRUCTION



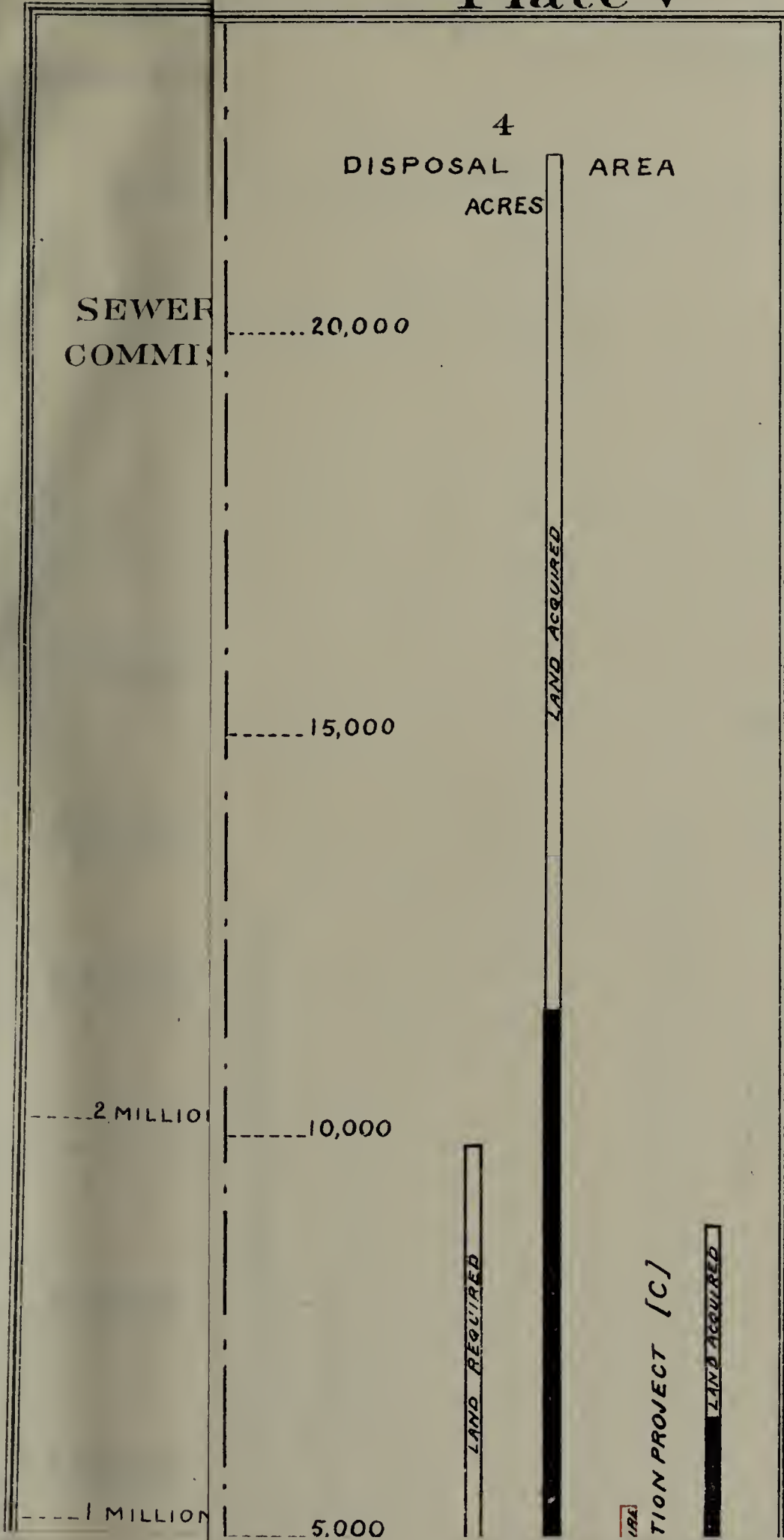
SEWERAGE COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

TOTAL ANNUAL EXPENSE INCLUDING INTEREST & SINKING FUND

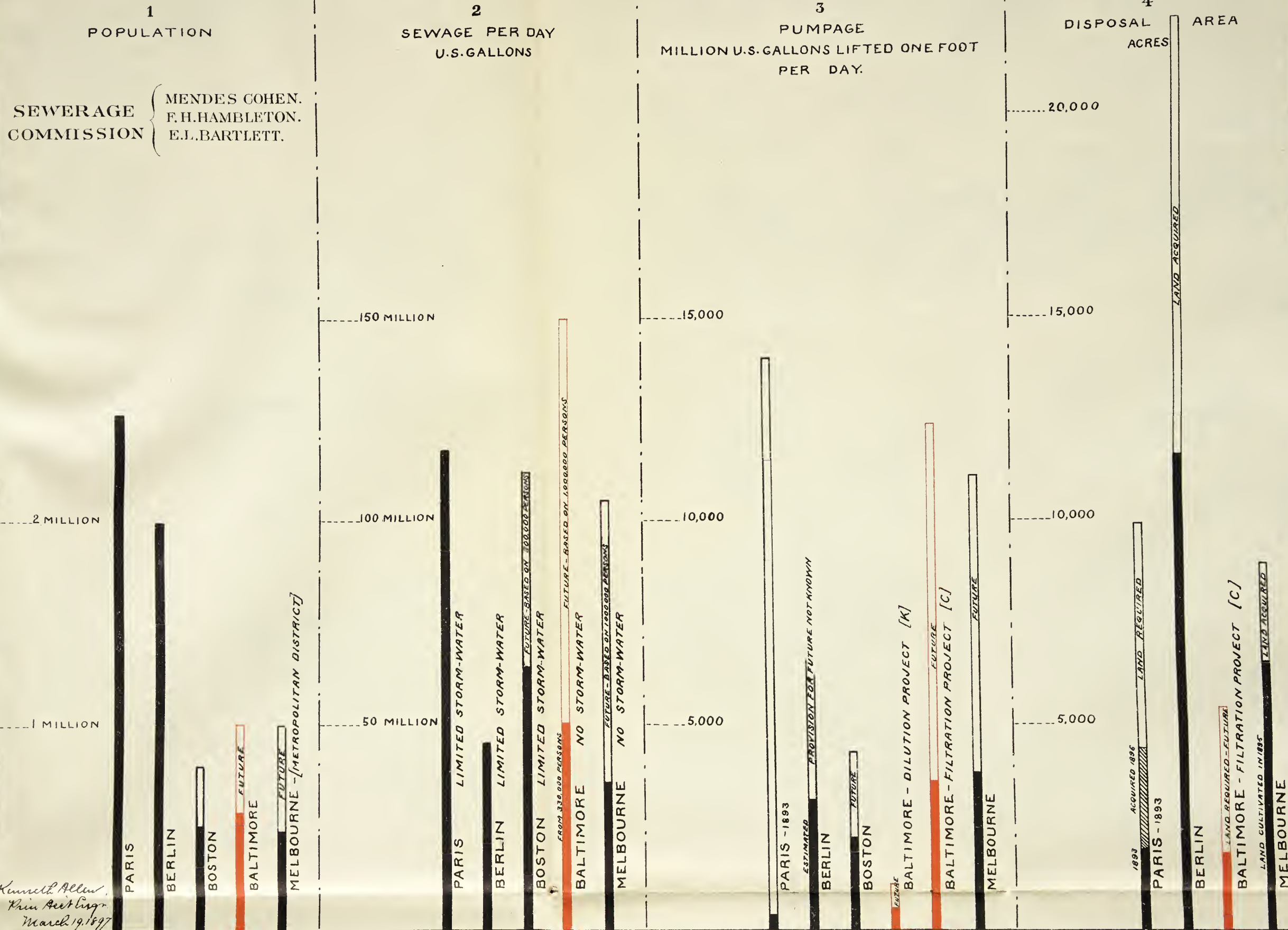


Kenneth Allen
Prin. Asst. Engr
March 17, 1897

Plate V



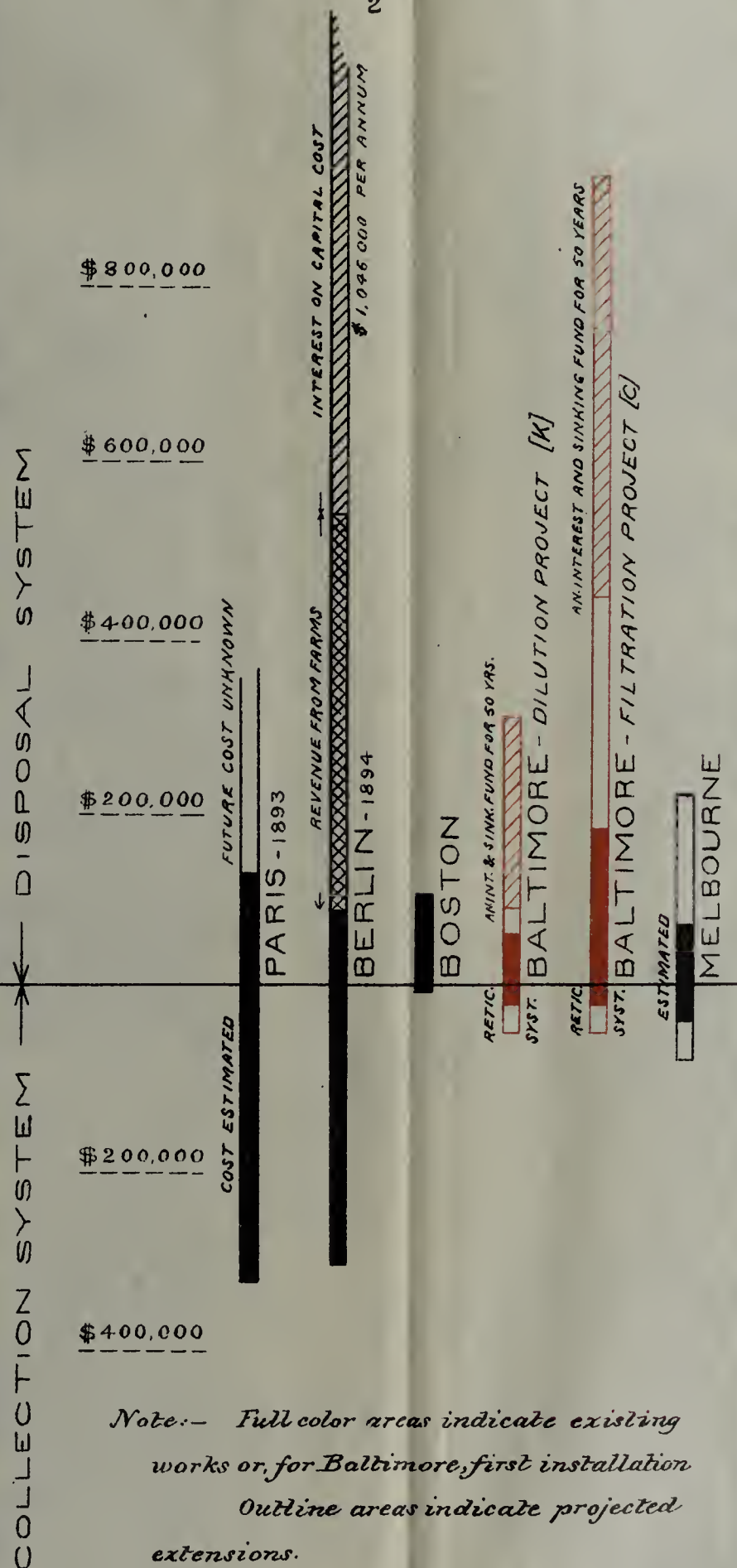
BALTIMORE SEWERAGE COMMISSION



Kenneth Allen,
Printed by
March 19, 1897

ANNUAL COST OF MAINTENANCE

2



*Note:— Full color areas indicate existing works or, for Baltimore, first installation
Outline areas indicate projected extensions.*

SEWERAGE COMMISSION

MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

Kenneth Allen
Prim. Asst. Eng'r
April 7. 1897

LIBRARY
UNIVERSITY OF ILLINOIS
URBANA

117-1117

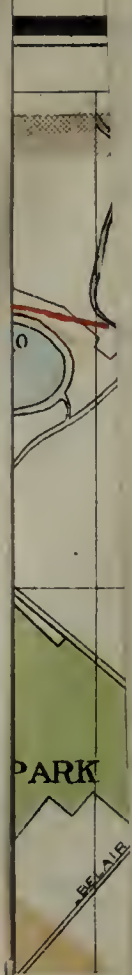
CHARGE COMMISSION

THOMAS M.D.

REVISION OF EXISTING

WATER DRAINAGE

1917



SEWERAGE COMMISSION
OF
BALTIMORE, MD.
MAP SHOWING LOCATION OF EXISTING
STORM-WATER DRAINS.
JANUARY 1897.

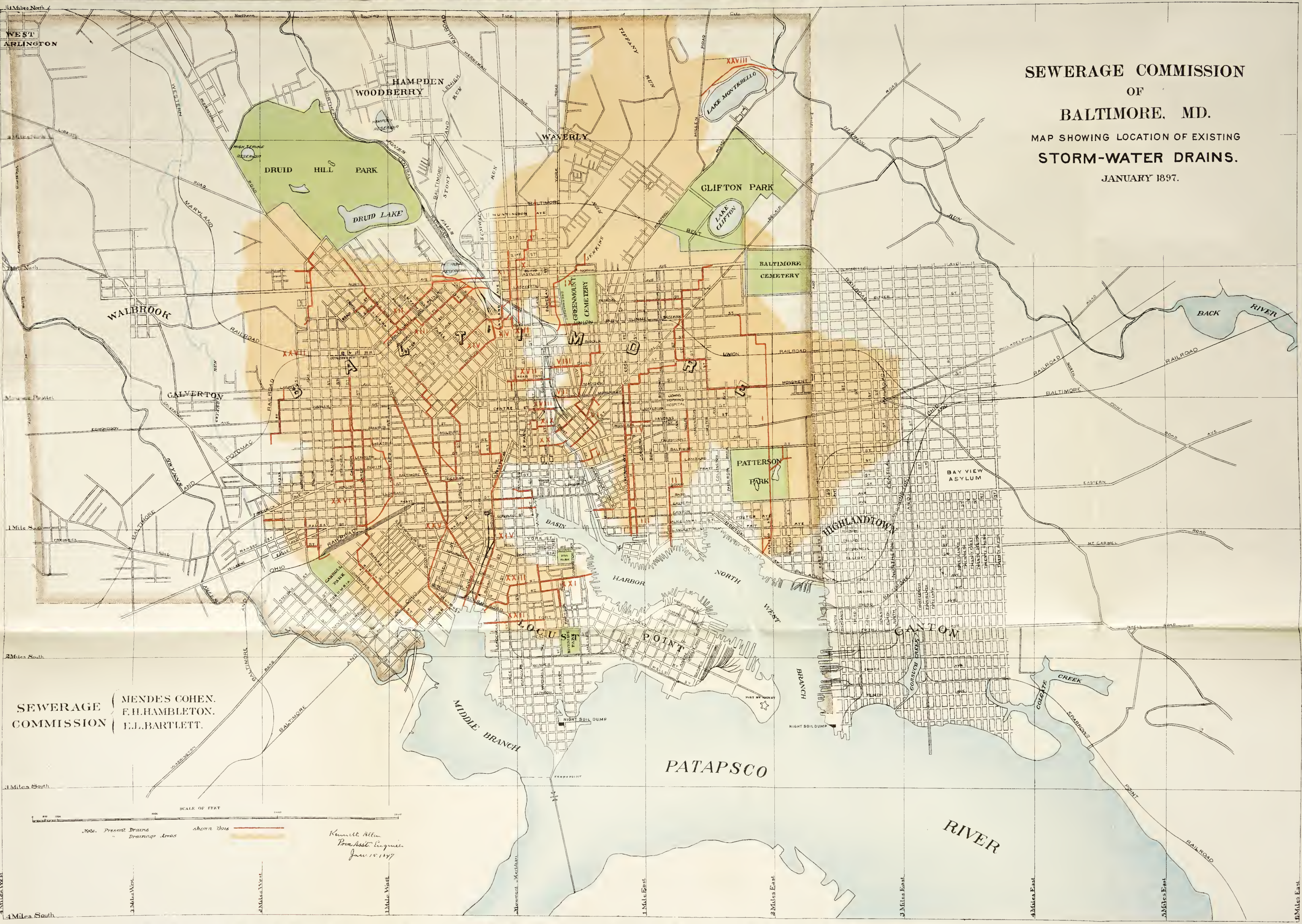


Plate VIII



LA MORE
LA MORE
LA MORE

BALTIMORE SEWERAGE COMMISSION CHART SHOWING TRACES OF ALL FLOATS SET ADRIFT FROM A,B,C,E&F, SO FAR AS OBSERVED. BASED UPON COAST CHART 136 U.S.C.&G.S. JULY 1897

0 Miles 1 2 3 4 5 6
Scale

NOTE:

FLOATS AGROUND INDICATED THUS X
FLOATS TAKEN FROM WATER " " " " O

*Kenneth Allen
Prim. Asst. Engr
July 23, 1897*



SEWERAGE
COMMISSION

MENDES COHEN.
F.H. HAMBLETON.
E.L. BARTLETT.

Plate IX



THE BAY OF
THE HAVEN OF
THE BAY OF

BALTIMORE SEWERAGE COMMISSION
CHART SHOWING
TRACES OF ALL FLOATS SET ADRIFT FROM K,
SO FAR AS OBSERVED.
BASED UPON COAST CHART 136 U.S.C.&G.S.
JULY 1897.

Scale
0 Miles 1 2 3 4 5 6

NOTE:

FLOATS AGROUND INDICATED THUS --- X
FLOATS TAKEN FROM WATER " --- O

Kenneth Allen
Prim. Des. Engr
July 23, 1897



SEWERAGE COMMISSION
MENDES COHEN.
F.H. HAMBLETON.
E.L. BARTLETT.



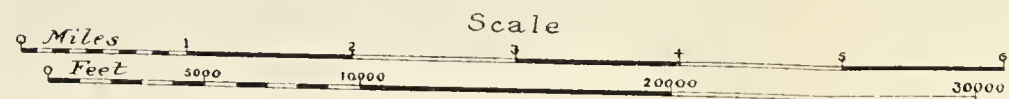
32° 20' 04"

SEWERAGE
COMMISSION

MENDES COHEN.
F.H. HAMBLETON.
E.J. BARTLETT.

BALTIMORE SEWERAGE COMMISSION
CHART SHOWING
THE PROBABLE DILUTION OF SEWAGE
AS INDICATED BY THE OBSERVED DISPERSION OF
FLOATS SET OUT FROM PROPOSED LOCATION OF OUTLET K
BASED UPON COAST CHART 136 U.S.C.&G.S.

JULY 1897.



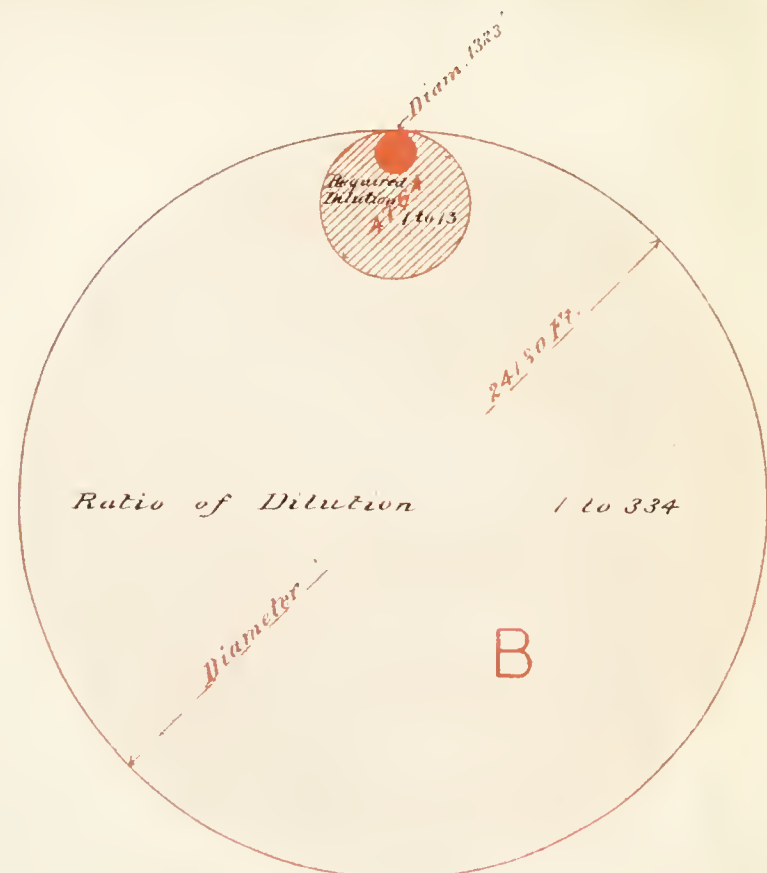
Kenneth Allen
Prim. Des. Engr
July 23, 1897

FLOATS SET ADRIFT				
		A.M.	2 1/2 HRS AFTER L.W.	
172	3.00			
173	4.00			
174	5.00			H.W.
175	5.05			
176	6.00			
177	6.30			
178	7.00			
179	7.30			
180	8.00			
181	8.30			
182	9.00			
183	9.30			
184	10.00			
185	10.30			
186	11.00			
187	11.30			
188	12.00	M.		L.W.
189	12.30	P.M.		
190	1.00			
191	2.00			
192	2.30			
*193	3.00			
*194	3.30			
*195	4.00			
196	5.00			
197	5.30			H.W.
198	6.00			
199	6.30			
200	7.00			
201	7.30			

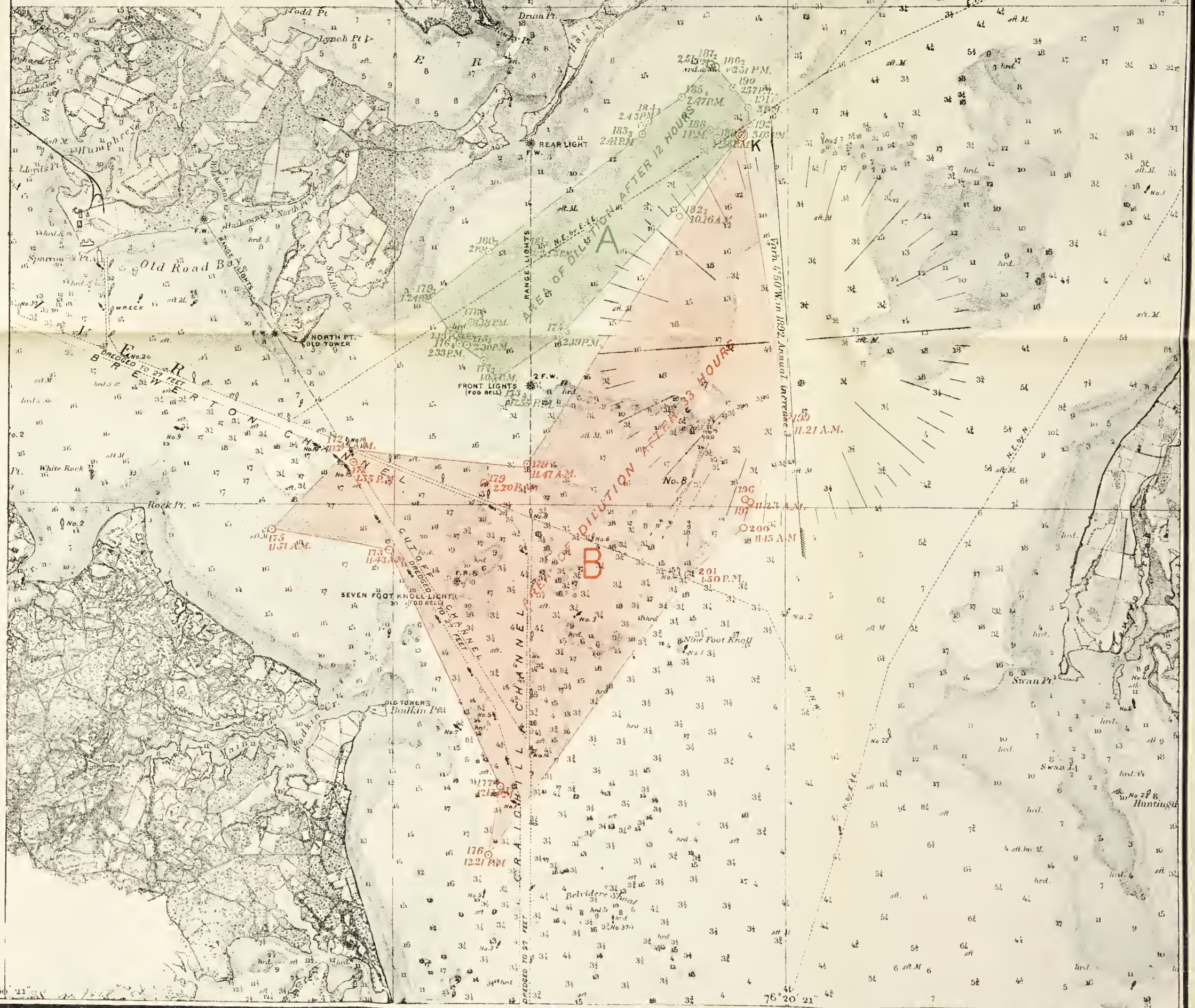
* Not seen after setting adrift.



AREAS OF CRUDE AND DILUTED SEWAGE FOR 12 HOURS
ASSUMING MEAN DEPTH OF 16 FEET



AREAS OF CRUDE AND DILUTED SEWAGE FOR 33 HOURS
ASSUMING MEAN DEPTH OF 20 FEET



COMMISSIONER OF

OF RAINFALL

IN THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

THE DISTRICT OF

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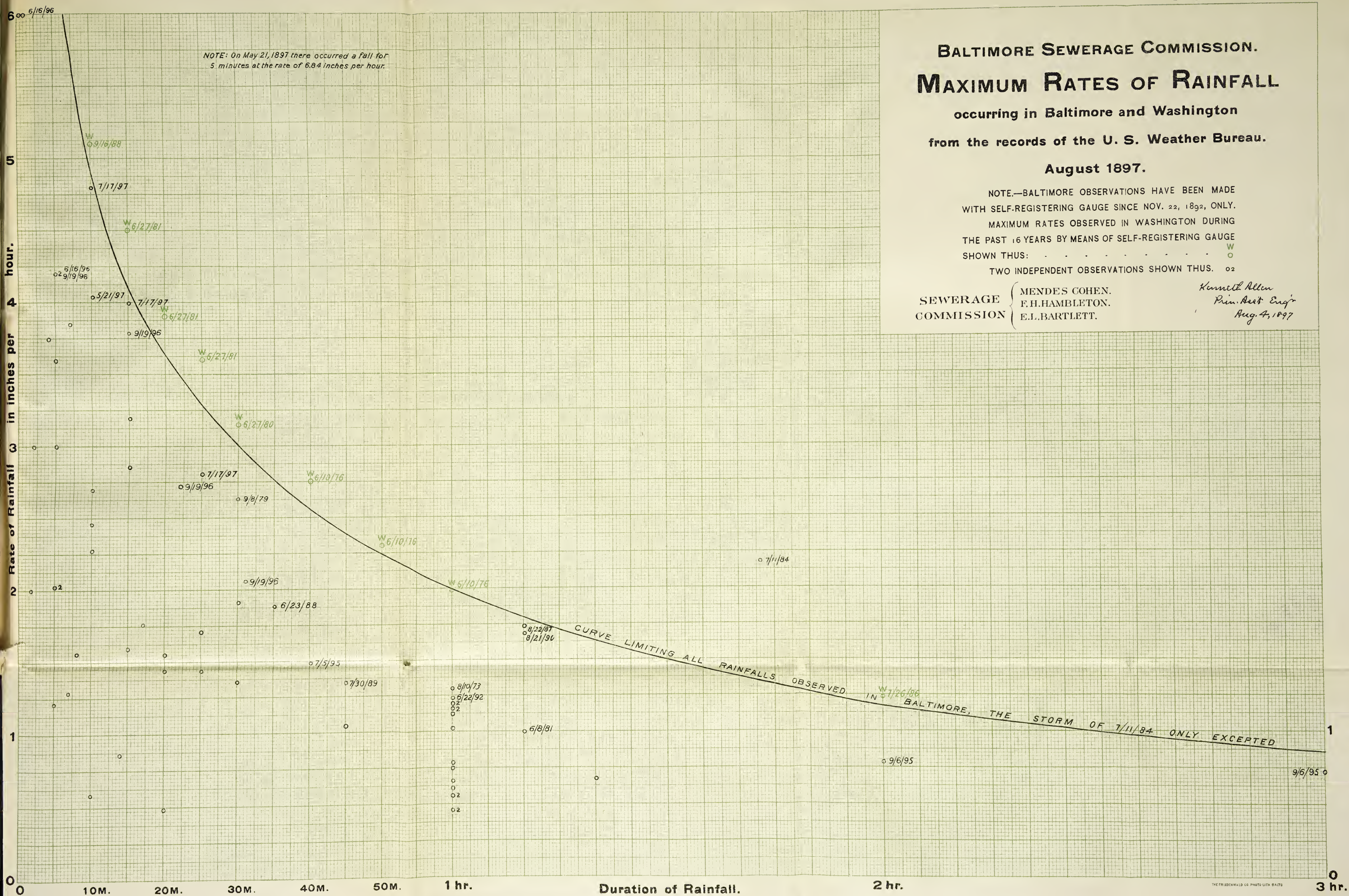
BALTIMORE SEWERAGE COMMISSION.
MAXIMUM RATES OF RAINFALL
 occurring in Baltimore and Washington
 from the records of the U. S. Weather Bureau.

August 1897.

NOTE.—BALTIMORE OBSERVATIONS HAVE BEEN MADE
 WITH SELF-REGISTERING GAUGE SINCE NOV. 22, 1892, ONLY.
 MAXIMUM RATES OBSERVED IN WASHINGTON DURING
 THE PAST 16 YEARS BY MEANS OF SELF-REGISTERING GAUGE
 SHOWN THUS: W
 TWO INDEPENDENT OBSERVATIONS SHOWN THUS. 02

SEWERAGE COMMISSION { MENDES COHEN.
 F.H.HAMBLETON.
 E.L.BARTLETT.

Kenneth Allen
 Prin. Asst. Eng'r
 Aug. 4, 1897



AGE PROJECTS
FOR THE
BALTIMORE

IN CHESAPEAKE BAY

MAP SHOWING

THE BALTIMORE WATERWORKS

AND

THE BALTIMORE TOWNSHIP

AND

THE BALTIMORE TOWNSHIP

AND

DECEMBER, 1886.





SEWERAGE
COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

C

11

100
100

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

DILUTION IN CHESAPEAKE BAY
MAP
SHOWING LOCATION OF MAIN OUTFALL SEWER
ALSO
LOCATION OF CHEMICAL PRECIPITATION TANKS
Jointly Presented

BY
Rudolph Hering AND Samuel M. Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896

NOTE
INDICATES PROPOSED ROUTE FOR OUTFALL SEWER
" ALTERNATE ROUTES " " "
Scale = 36,500
0 1/2 1 2 3 4 5 6 7 8 9 10 11 12 Miles



SEWERAGE COMMISSION { MENDES COHEN.
F.H. HAMBLETON.
E.L. BARTLETT.

S LORE

SEWERAGE COMMISSION
 MENDES COHEN.
 F.H. HAMBLETON.
 E.L. BARTLETT.

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

DILUTION IN CHESAPEAKE BAY
 PROFILE AND SECTIONS
 OF
 OUTFALL SEWER

ALSO
 PLAN, PROFILE AND SECTION OF SIPHON UNDER BEAR CREEK
 Jointly Presented

BY
 Rudolph Hering and Samuel M. Gray
 CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
 NOVEMBER, 1896.

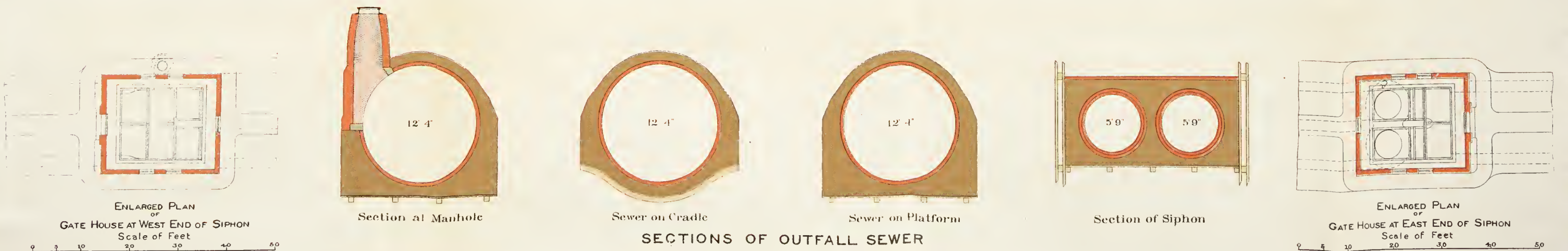
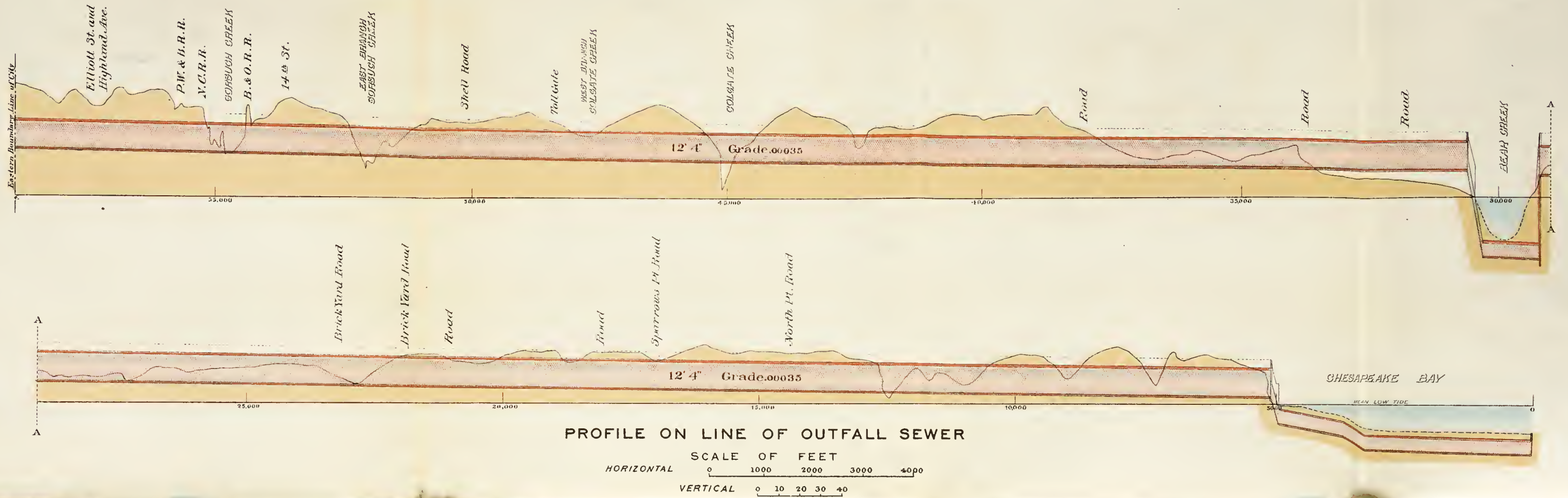


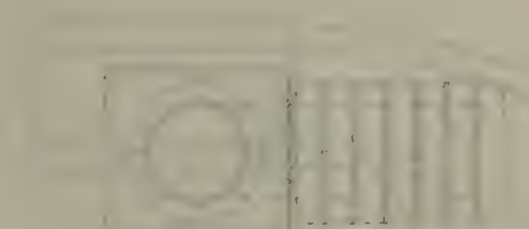
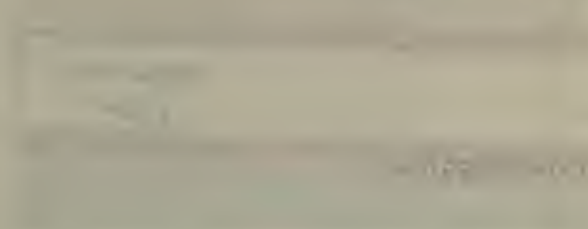
Plate D

ST

MOORE

VAB 2

DETACHED



Architect's Office

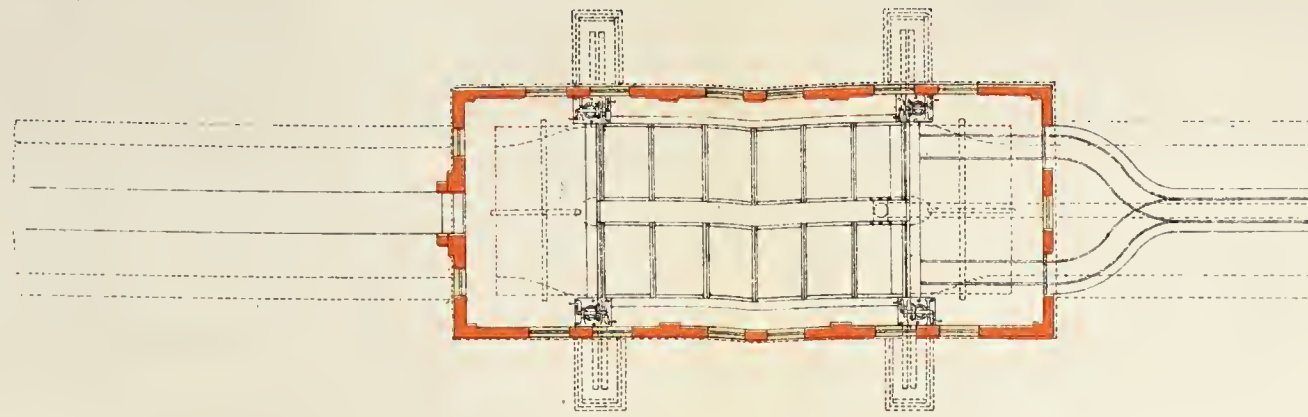
SEWERAGE COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

DILUTION IN CHESAPEAKE BAY
PLAN OF
SETTLING BASIN, GATE HOUSE AND OUTFALL

Jointly Presented
BY
Rudolph Hering and Samuel M. Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.

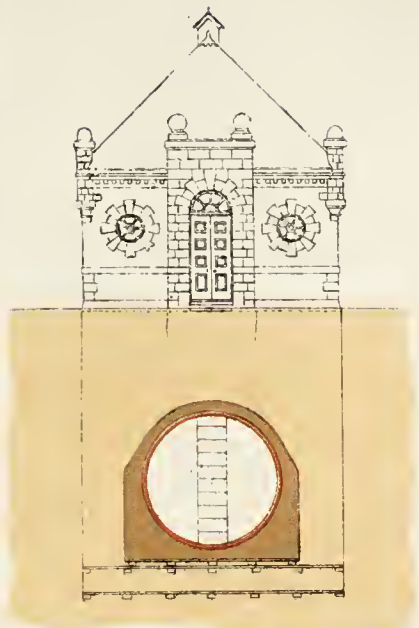
SCALE OF FEET
0 10 20 30 40 50 60



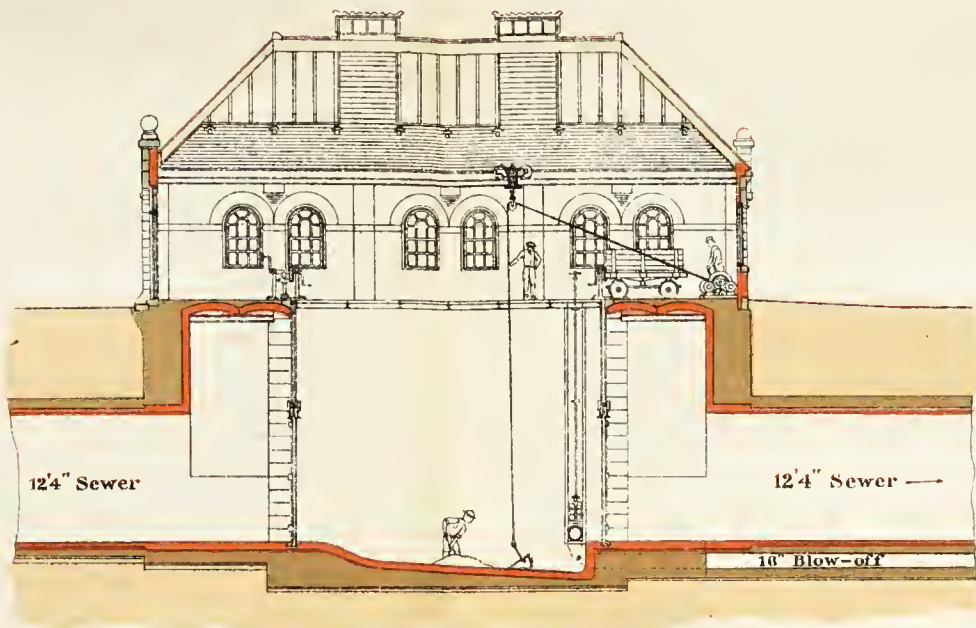
Plan



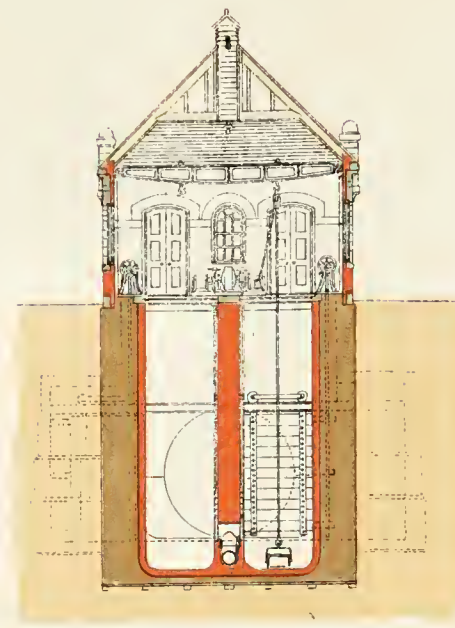
12' 4" Diam.



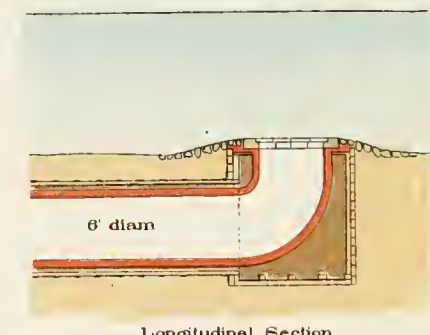
Front Elevation



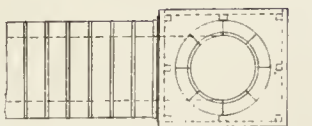
Longitudinal Section



Transverse Section



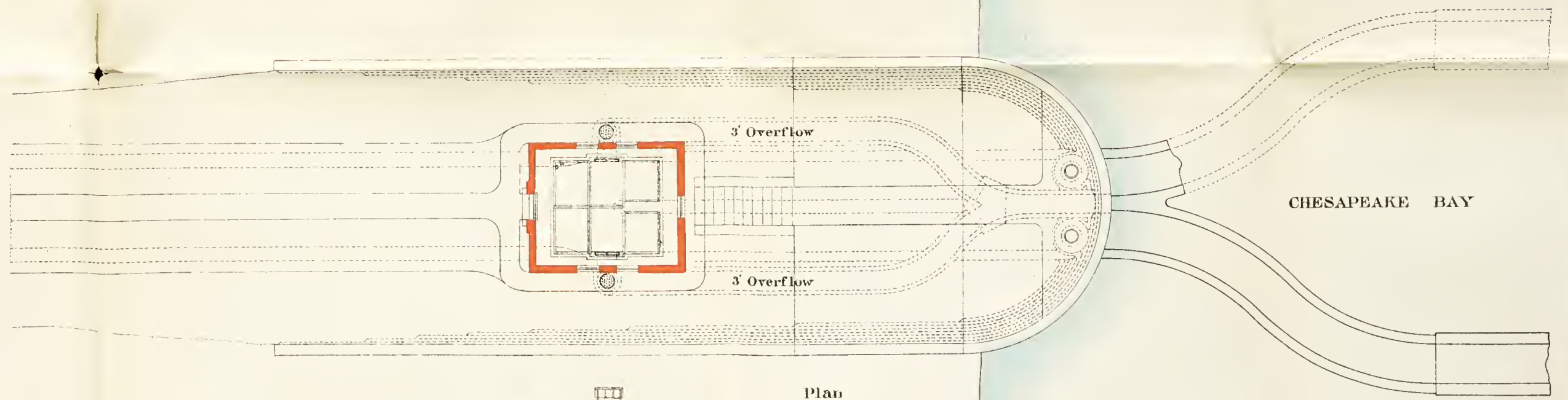
Longitudinal Section



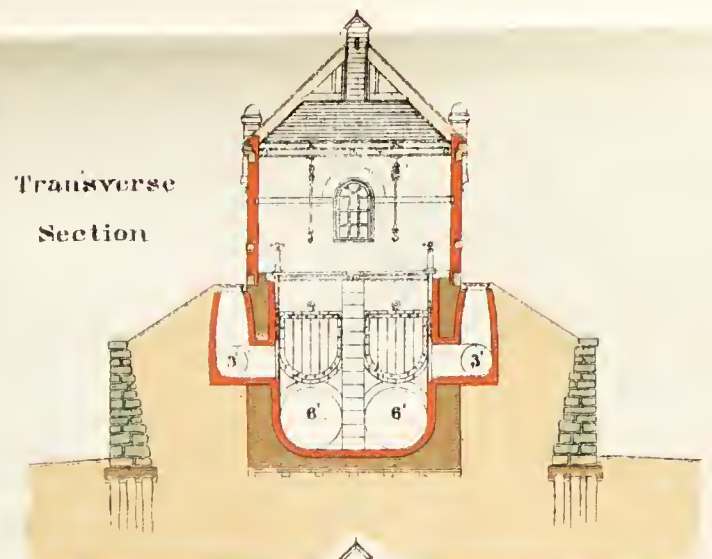
Plan

DETAILS OF OUTLET DISCHARGE

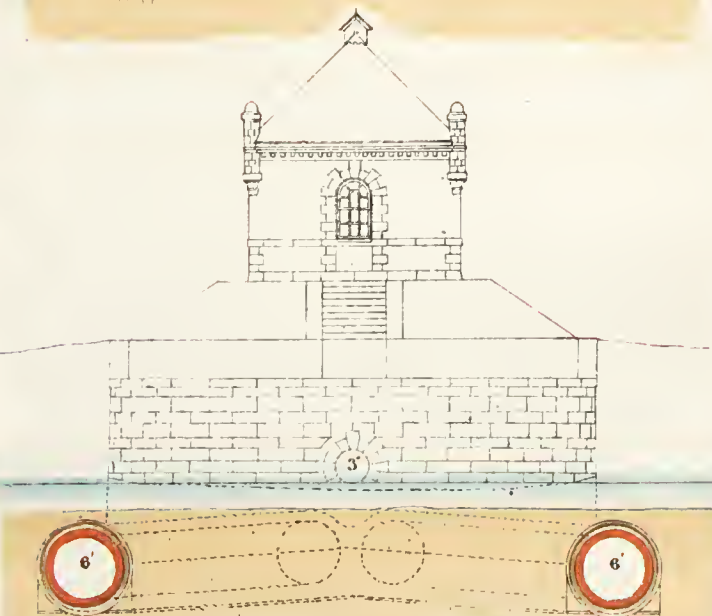
SETTLING BASIN



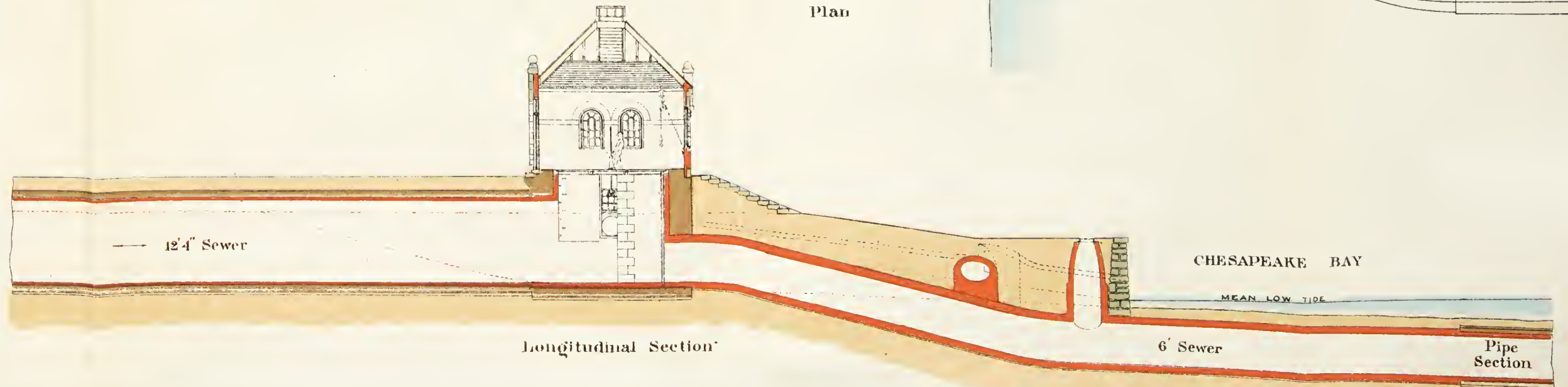
Plan



Transverse Section



Elevation from the Bay



Longitudinal Section

OUTFALL GATE HOUSE AND OVERFLOW

TS

ORE

ON

GREEN

8

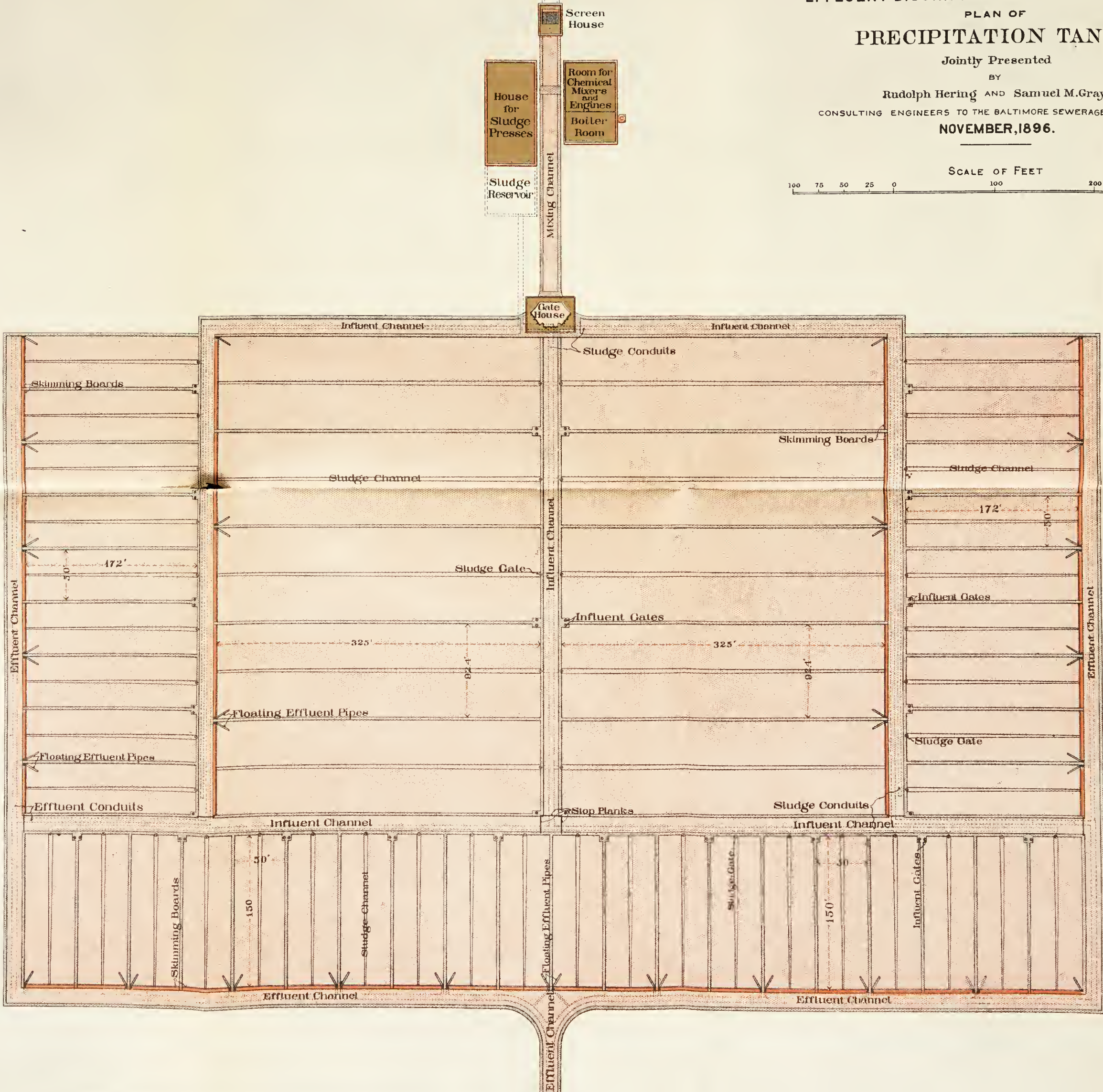
COMMISSION

100

SEWERAGE
COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

SEWERAGE PROJECTS
FOR THE
CITY OF BALTIMORE
CHEMICAL PRECIPITATION
EFFLUENT DISCHARGED INTO COLGATE CREEK
PLAN OF
PRECIPITATION TANKS

Jointly Presented
BY
Rudolph Hering AND Samuel M.Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.



SECTION OF THE
THEATRE
AT WASHINGTON

SECTION OF THE
THEATRE
AT WASHINGTON

ST. 12
10
VAB 3



SECTION OF THE THEATRE AT WASHINGTON

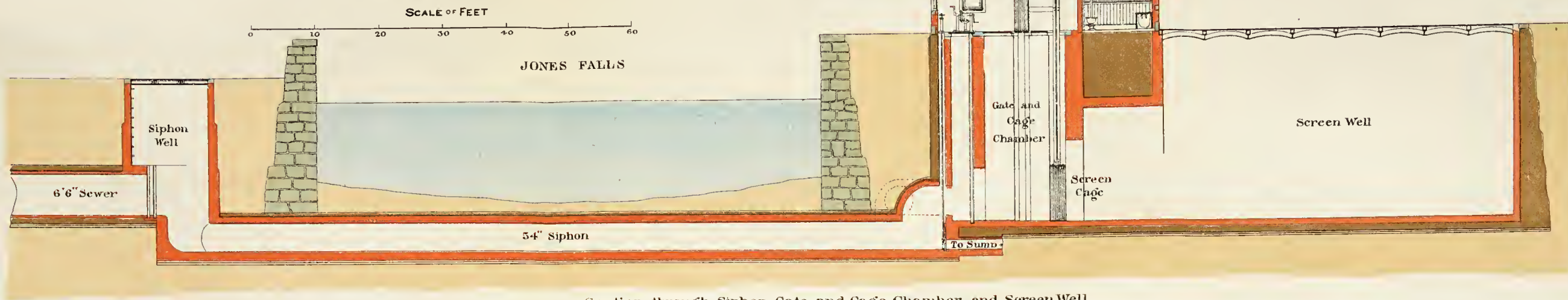
SEWERAGE PROJECTS
FOR THE
CITY OF BALTIMORE

DILUTION IN CHESAPEAKE BAY
PLAN OF
PUMPING STATION

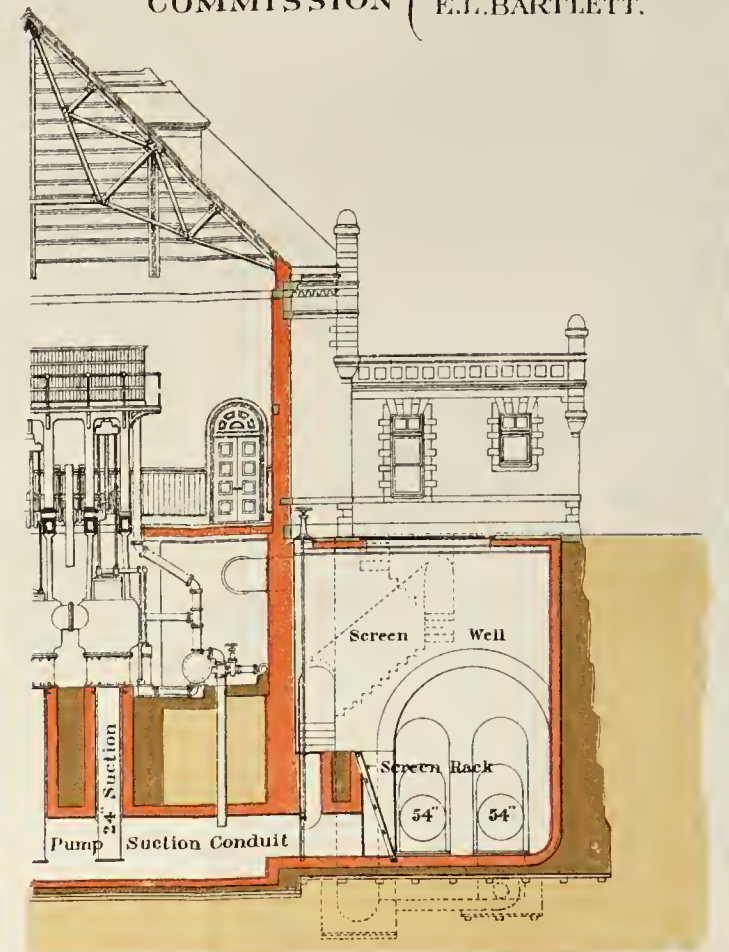
Jointly Presented
BY
Rudolph Hering AND Samuel M. Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.

SEWERAGE
COMMISSION

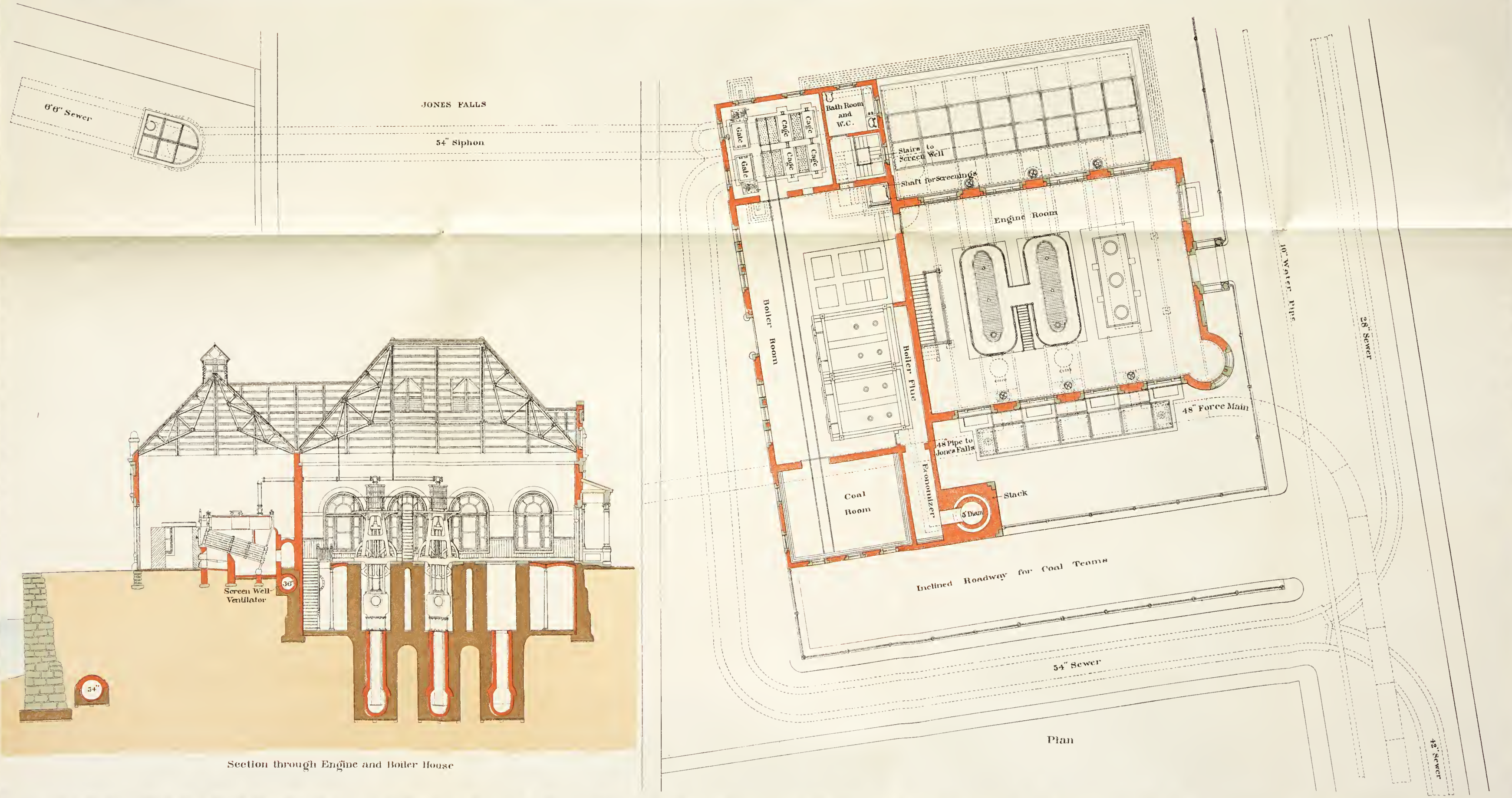
MEDES COHEN.
F.H. HAMBLETON.
E.L. BARTLETT.



Section through Siphon, Gate and Cage Chamber, and Screen Well



Transverse Section through Screen Well



Section through Engine and Boiler House

1946

HATTIMORE

THE ANNE ARUNDEL COUNTY

MAP SHOWING

SEWER DISTRICTS

AND

DISTRICT SEWERS

AND

BY

WILLIAM H. GRIFFIN, CIVIL ENGINEER

CONSULTING ENGINEER

OCTOBER, 1946



Rudolph Hering AND Samuel M. Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.

NOTE

5	HIGH LEVEL INTERCEPTORS	
	LOW	"
	AREA SEWERED BY GRAVITY	
	"	"
	"	" PUMPING

AREA SEWERED BY GRAVITY
.. .. PUMPING

$\frac{1}{2}$	$\frac{1}{4}$	1 Mile
---------------	---------------	--------

115

(continued)

PROJECTS

THE

ATLANTIC

3 ARUNDEL COUNTY

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R. 21 ARUNDEL

ARUNDEL

AR

ARUNDEL

ARUNDEL

ARUNDEL

18 454274

SEWERAGE
COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

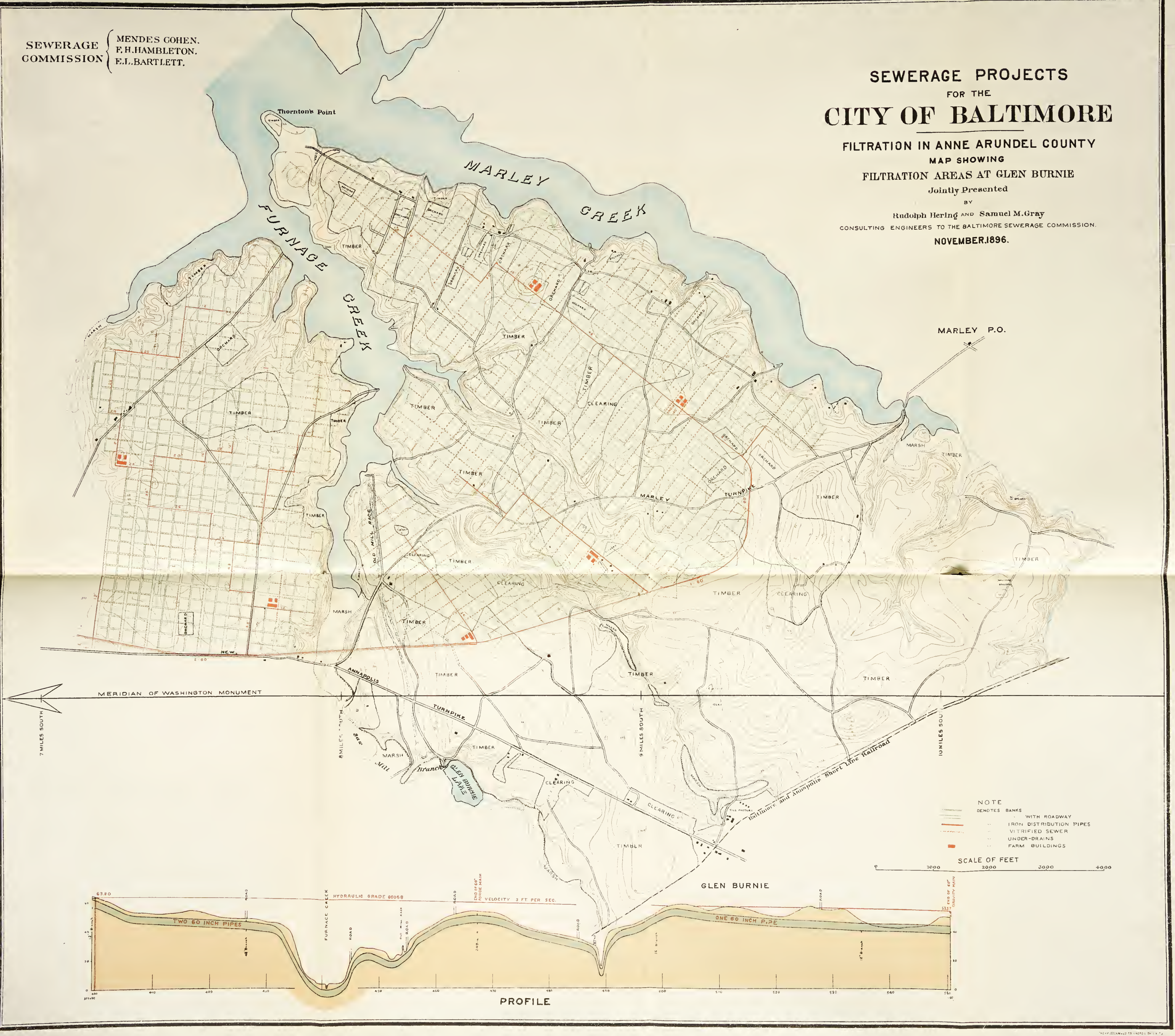
SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

FILTRATION IN ANNE ARUNDEL COUNTY

MAP SHOWING
FILTRATION AREAS AT GLEN BURNIE

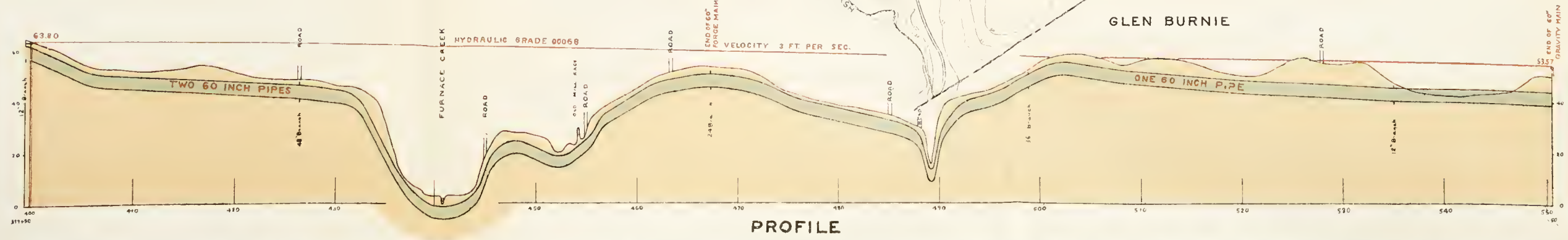
Jointly Presented
BY

Rudolph Hering and Samuel M.Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.



NOTE
DENOTES BANKS WITH ROADWAY
--- IRON DISTRIBUTION PIPES
--- VITRIFIED SEWER
--- UNDER-DRAINS
--- FARM BUILDINGS

SCALE OF FEET
0 1000 2000 3000 4000



PROFILE

Table 1

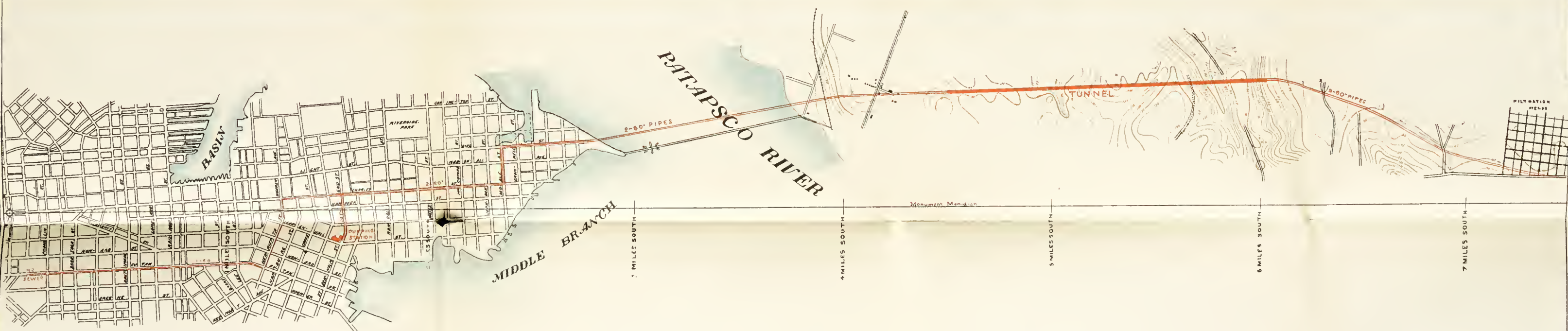
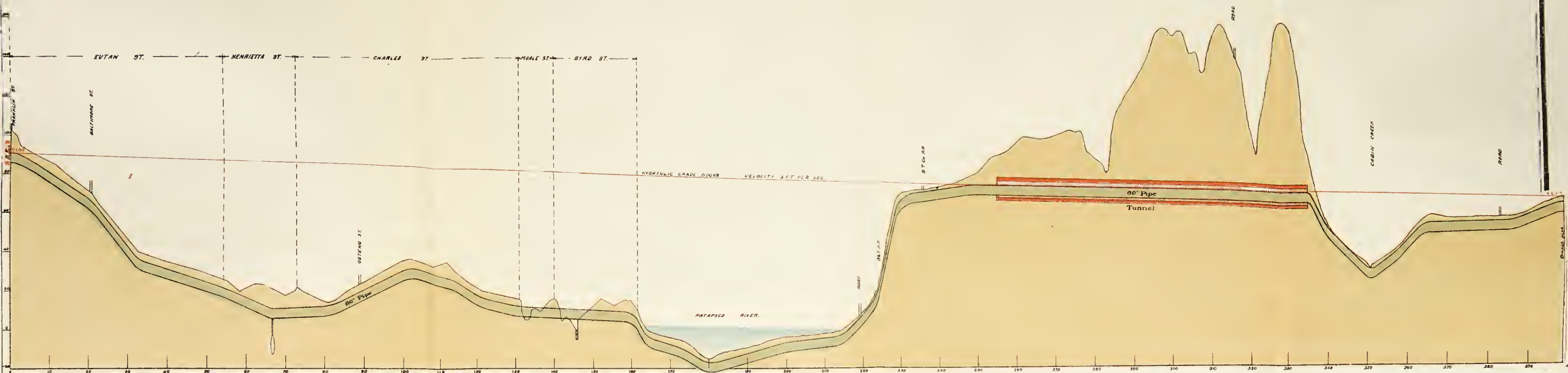


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2E



SEWERAGE
COMMISSION

MEDES COHEN.
F.H.HAMBLETON.
E.J.L.BARTLETT.



SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

FILTRATION IN ANNE ARUNDEL COUNTY

MAP SHOWING
PLAN AND PROFILE

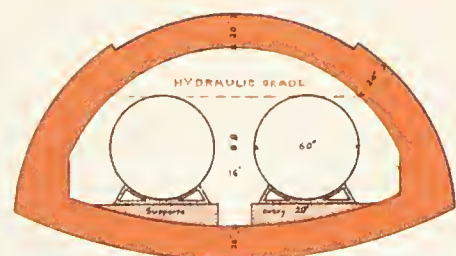
OF
DISCHARGE MAINS ALSO SECTIONS OF TUNNEL AND RIVER CROSSING

Jointly Presented
BY

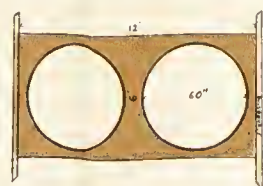
Rudolph Hering and Samuel M. Gray

CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION

NOVEMBER, 1896

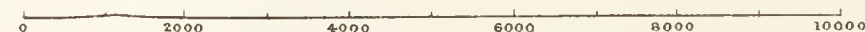


Section of Tunnel



Section of River Crossing

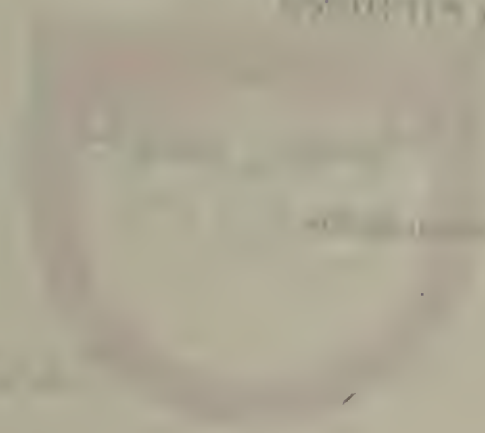
SCALE OF FEET



LECTS

CHURCH

DEPT. COUNTY
OFFICE



OFFICE OF THE
SHERIFF



SEWERAGE
COMMISSION

MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

FILTRATION IN ANNE ARUNDEL COUNTY
SECTIONS OF INTERCEPTING SEWERS AND SIPHONS

Jointly Presented

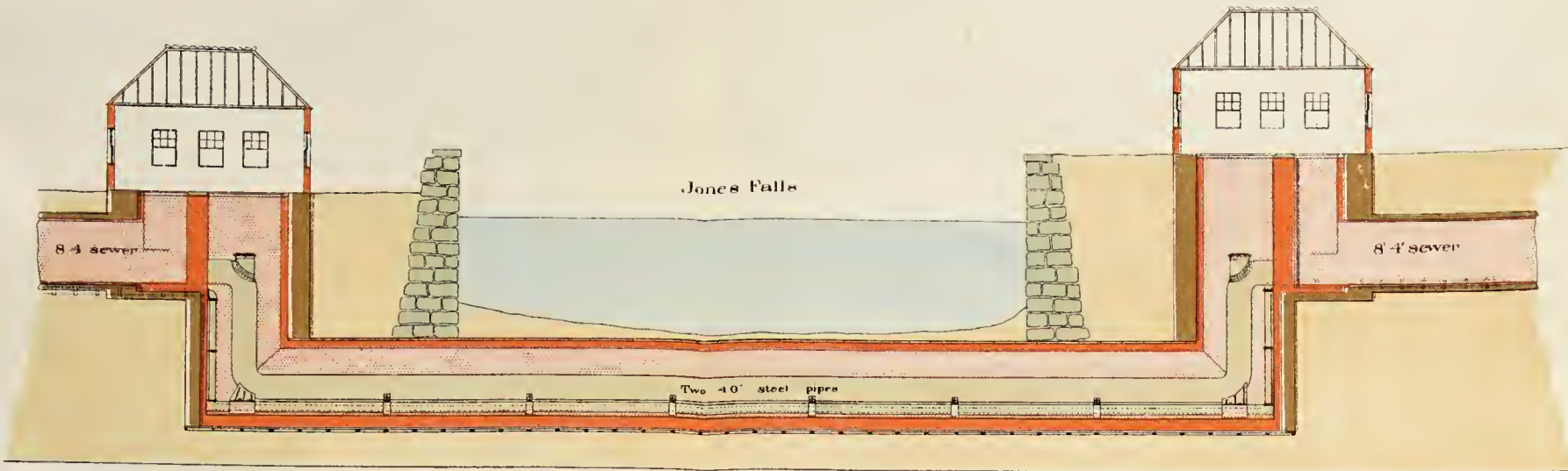
BY

Rudolph Hering AND Samuel M. Gray

CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.

NOVEMBER, 1896.

Scale $\frac{1}{10}$ inch = 1 foot.



Siphon under Jones Falls

Low Level Interceptor

Scale of Feet.

0 10 20 30 40 50 60 70 80

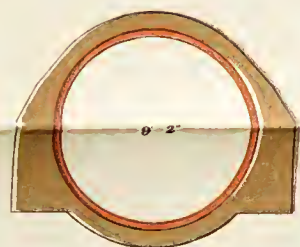


Siphon under Jones Falls

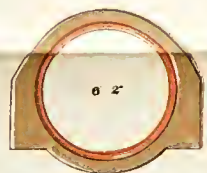
High Level Interceptor

Scale of Feet.

0 50 100 150 200



Eutaw St.



Eutaw St. to Hoffman St.



Argyle Ave. to Carey St.



Mulberry St. to Gilmer St.



Fayette St. to Baltimore St.



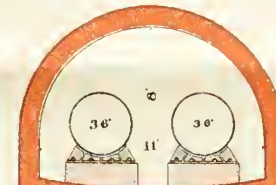
Ensor St. to Harford Ave.



Harford Ave. to Hopkins Ave.



Twenty-first St. to Ensor St.



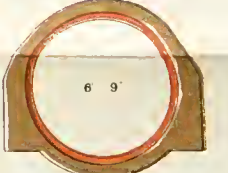
McMechen St. to Hargrove Al.



McMechen St. to Twenty-first St.



Camel Al. to McMechen St.



Eutaw St. to Camel Al.

WESTERN HIGH LEVEL INTERCEPTOR

EASTERN HIGH LEVEL INTERCEPTOR



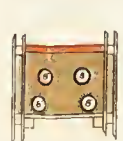
Charles St. to Williams St.



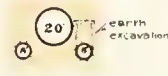
Williams St. to Battery Ave.



Battery Ave. to Clement St.



Siphon under Cross St.



Hull St. to Garrett Ave.



Allen St. to Hull St.



Railroad Tracks to Clement St.



Creek to Railroad Tracks



Marshall St. to Creek



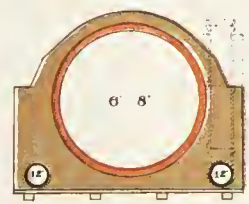
Fort Ave. to Marshall St.



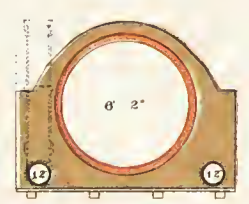
Stockholm St. to Fort Ave.

YORK STREET INTERCEPTOR

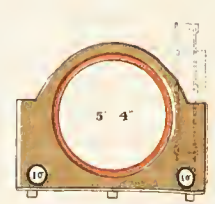
LOCUST POINT INTERCEPTOR



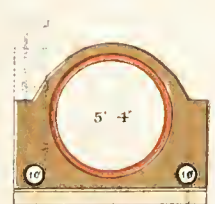
Front St. to Central Ave.



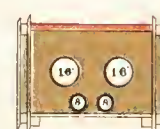
Central Ave. to Boston and Windsor Sts.



Boston and Windsor Sts. to near Harris Creek



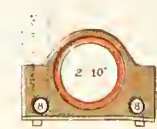
Harris Creek, 1250 feet westerly



Siphon under Harris Creek



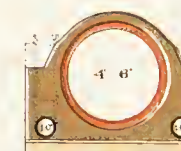
Harris Creek, 1250 feet easterly



Near Harris Creek to Third St.



Bush St. to Putnam St.



Ostend St. to Bush St.



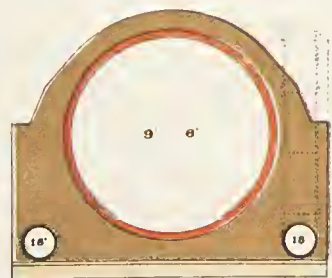
Stockholm St. to Ostend St.



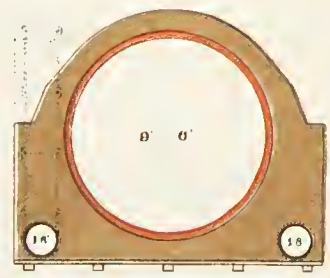
Lendenhall St. to Russell St.

EASTERN LOW LEVEL INTERCEPTOR CONTINUED

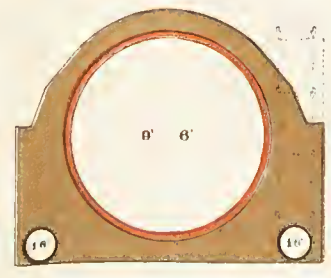
WESTERN LOW LEVEL INTERCEPTOR



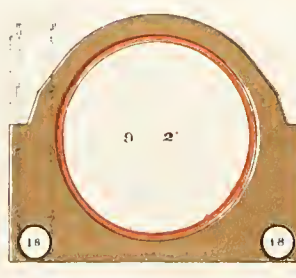
Stockholm St. to West St.



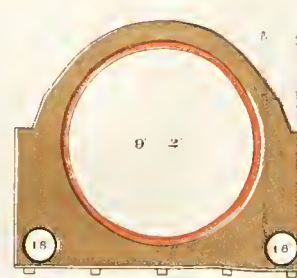
West St. to Hamburg St.



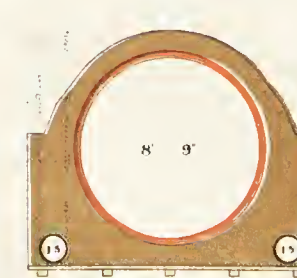
Hamburg St. to York St.



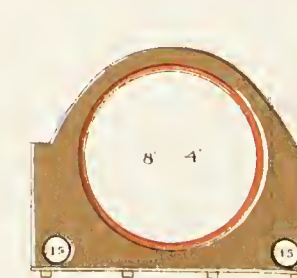
York St. to Lee St.



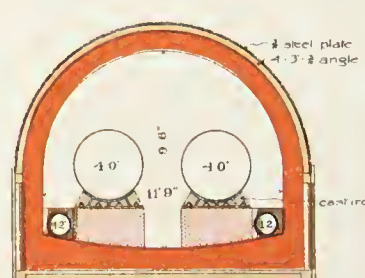
Lee St. to Balderston St.



Balderston St. to Centre Market



Centre Market to Front St.



Siphon under Jones Falls

EASTERN LOW LEVEL INTERCEPTOR

EDER ST. * MIL

BALTIMORE ST.

FRANKLIN ST.

MILTON PLACE
SCHROEDER ST.



STC

MOORE

EL COUNTY

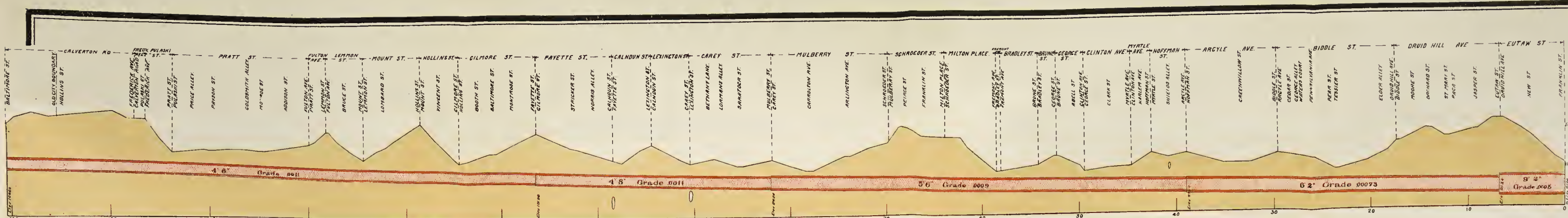
ROCK

THE

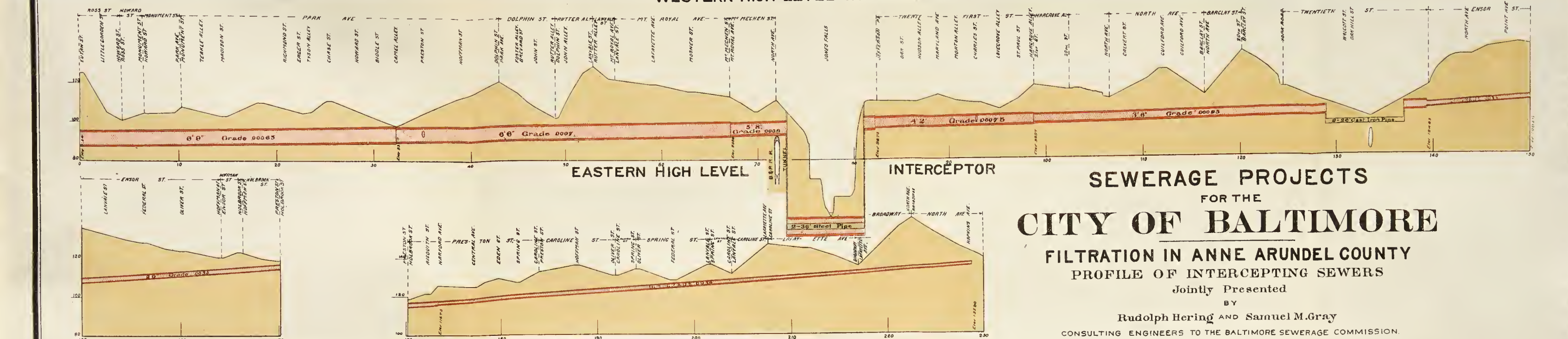
OF THE

NOT





WESTERN HIGH LEVEL INTERCEPTOR

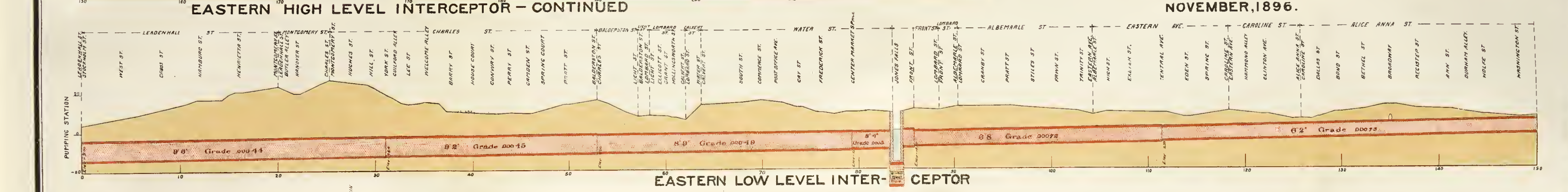


EASTERN HIGH LEVEL INTERCEPTOR

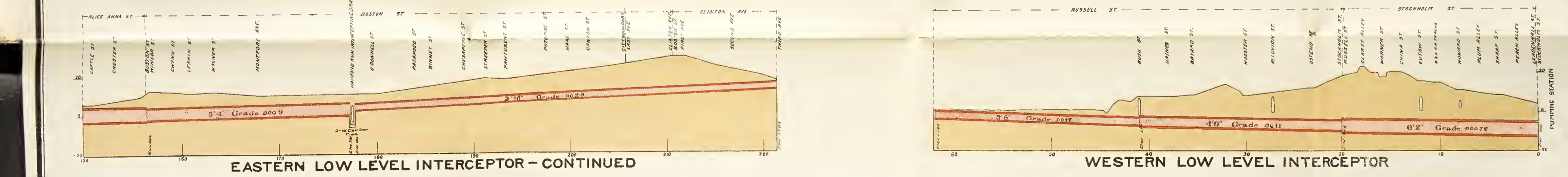
INTERCEPTOR

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

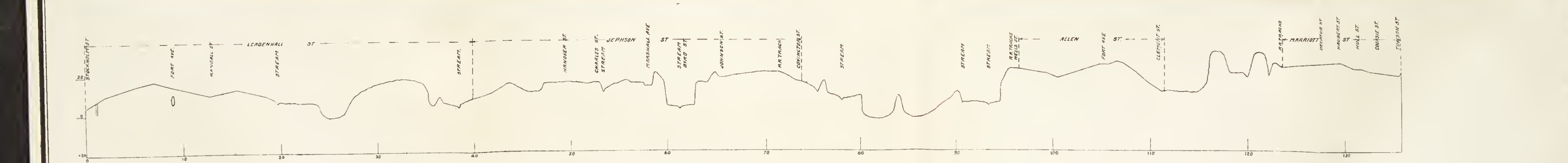
FILTRATION IN ANNE ARUNDEL COUNTY
PROFILE OF INTERCEPTING SEWERS
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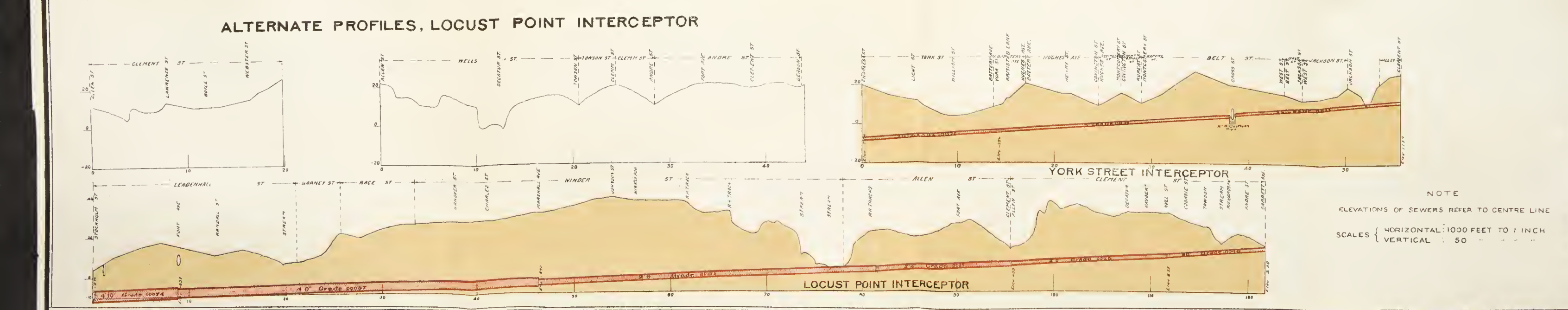
EASTERN LOW LEVEL INTERCEPTOR



WESTERN LOW LEVEL INTERCEPTOR



ALTERNATE PROFILES, LOCUST POINT INTERCEPTOR



YORK STREET INTERCEPTOR

NOTE
ELEVATIONS OF SEWERS REFER TO CENTRE LINE
SCALES { HORIZONTAL 1000 FEET TO 1 INCH
VERTICAL 50 " " "



View of the building from the front (left) and from the side (right).

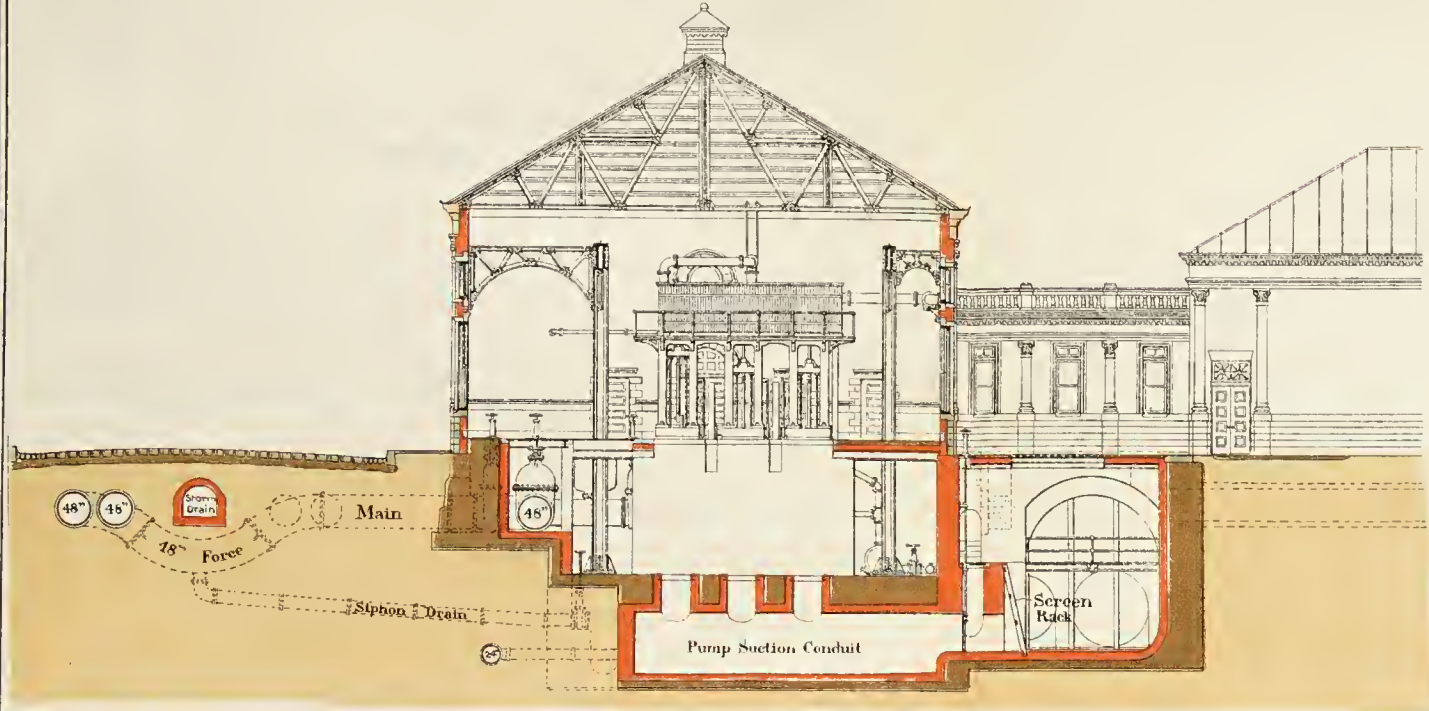
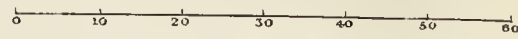
UNIVERSITY OF CHICAGO
LIBRARY
1955

SEWERAGE PROJECTS FOR THE CITY OF BALTIMORE

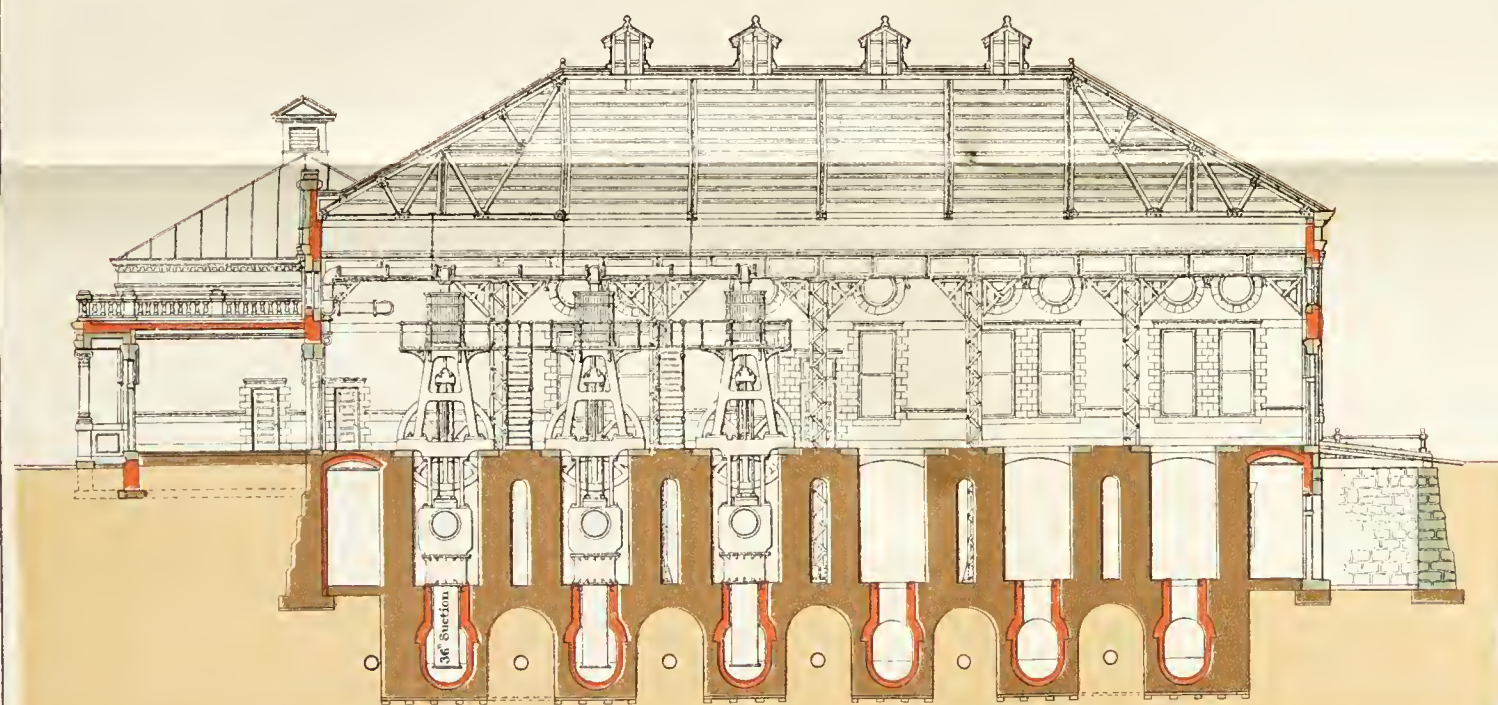
FILTRATION IN ANNE ARUNDEL COUNTY PLAN OF PUMPING STATION

Jointly Presented
BY
Rudolph Hering and Samuel M. Gray
CONSULTING ENGINEERS TO THE BALTIMORE SEWERAGE COMMISSION.
NOVEMBER, 1896.

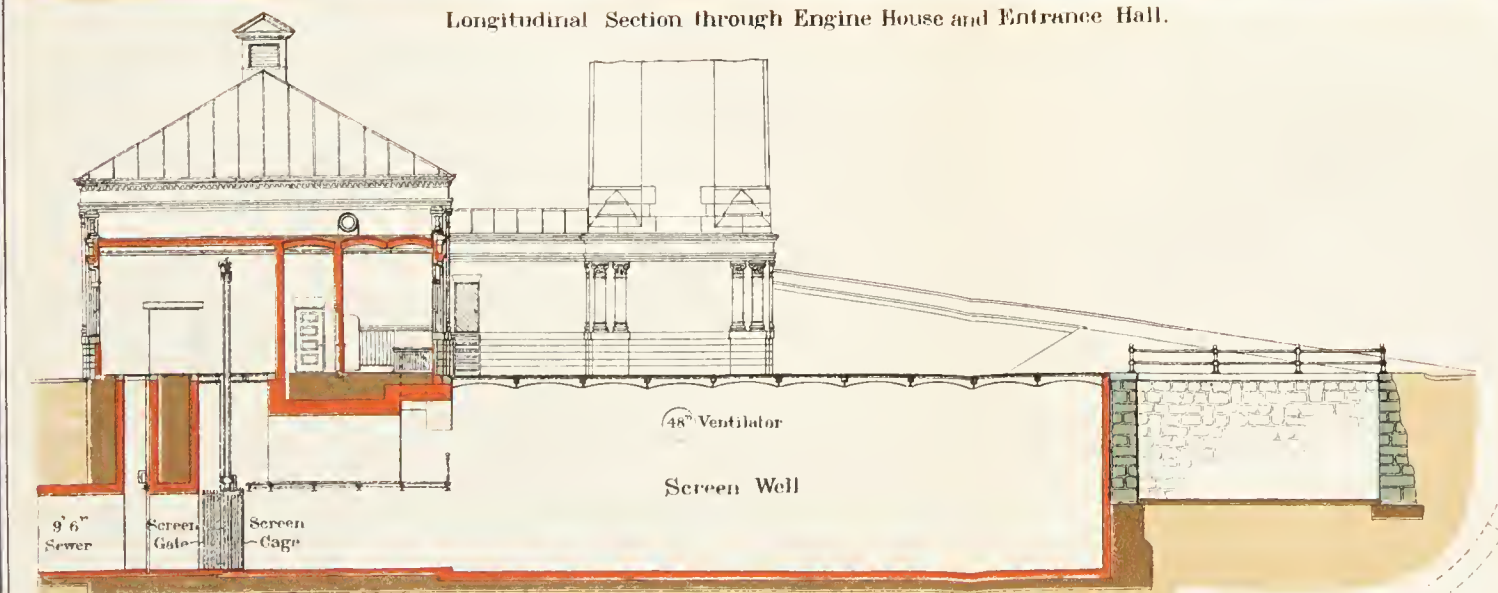
SCALE OF FEET



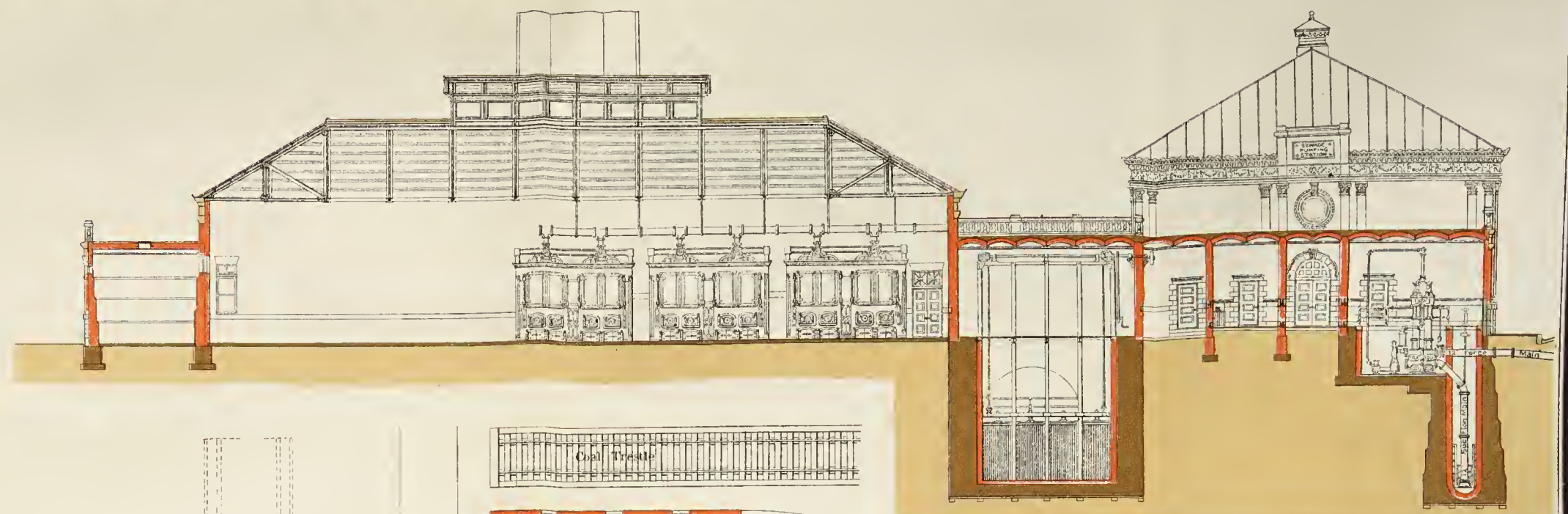
Cross Section through Engine House and Screen Well.



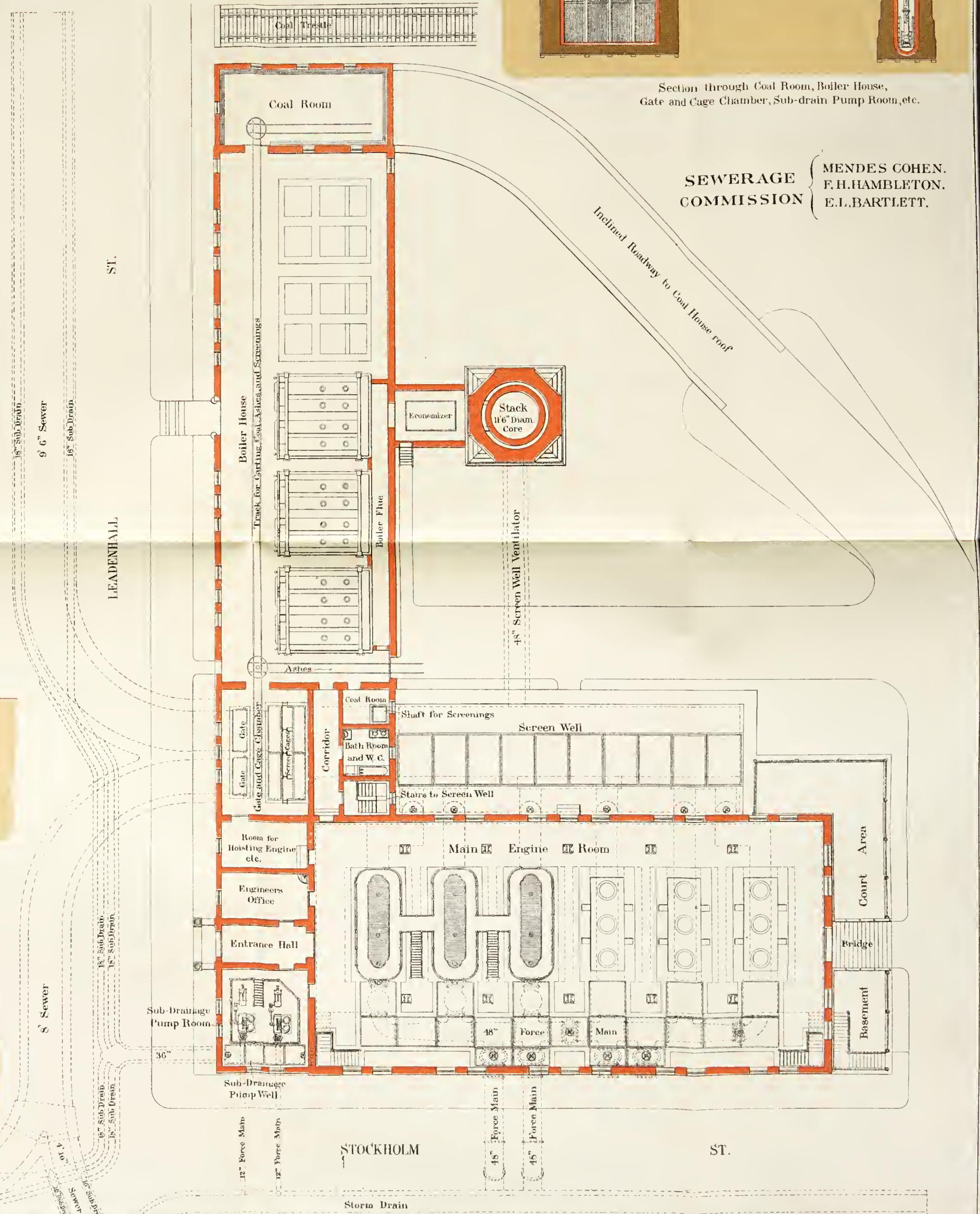
Longitudinal Section through Engine House and Entrance Hall.



Section through Gate and Cage Chamber and Screen Well.



Section through Coal Room, Boiler House,
Gate and Cage Chamber, Sub-drain Pump Room, etc.



SEWERAGE COMMISSION
MENDES COHEN.
F.H. HAMBLETON.
E.L. BARTLETT.

PROJECTS

ALTIMORE

MAP

THROUGH ROUTES

1901

Scale 1:100,000

1888



Plate N

E RAINFALLS

cities of

TIMORE, and WASHINGTON

in the

MARYLAND

25 years or more.

ailed from

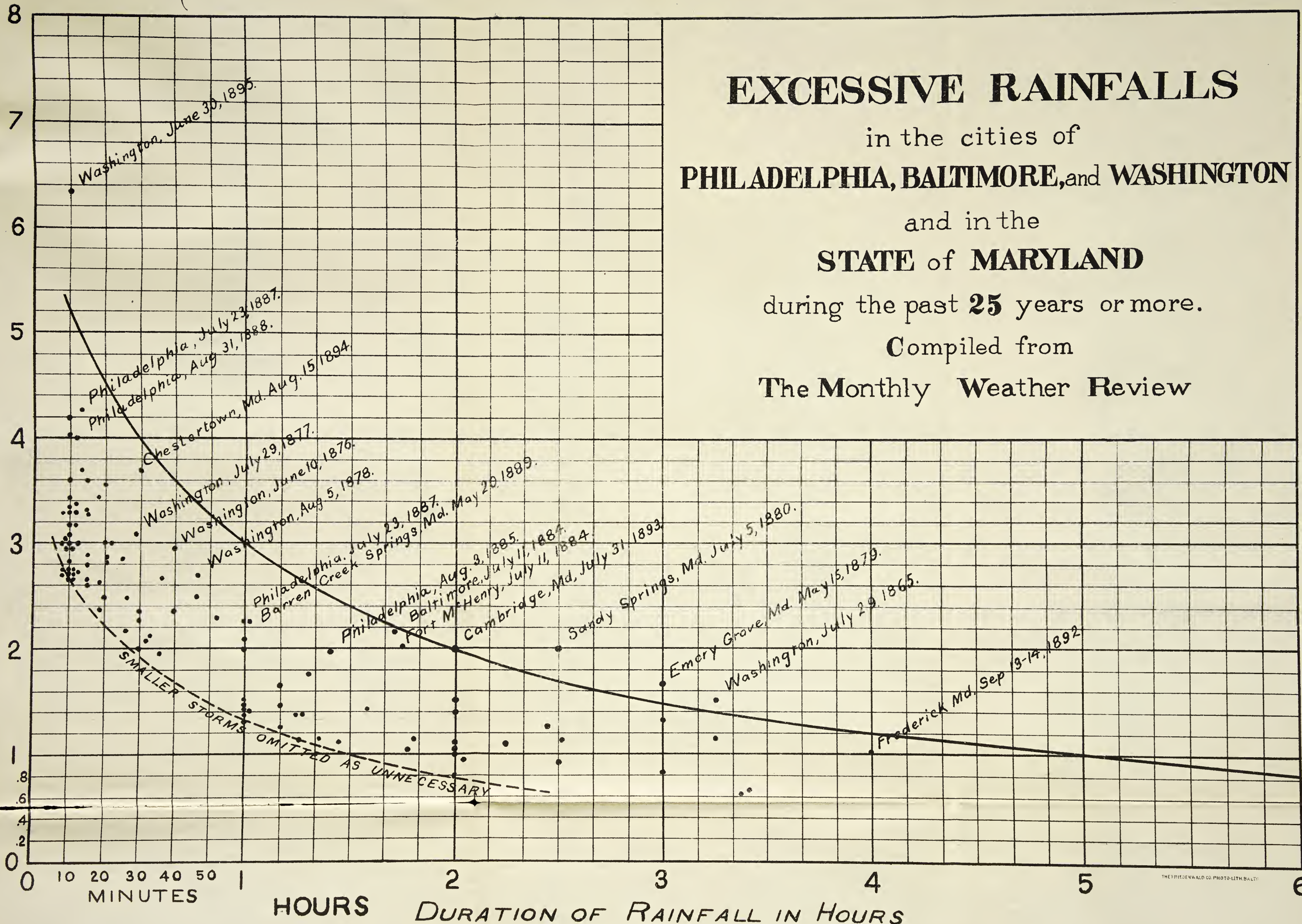
Weather Review

[illegible]

EXCESSIVE RAINFALLS

in the cities of
PHILADELPHIA, BALTIMORE, and WASHINGTON
and in the
STATE of MARYLAND
during the past **25** years or more.
Compiled from
The Monthly Weather Review

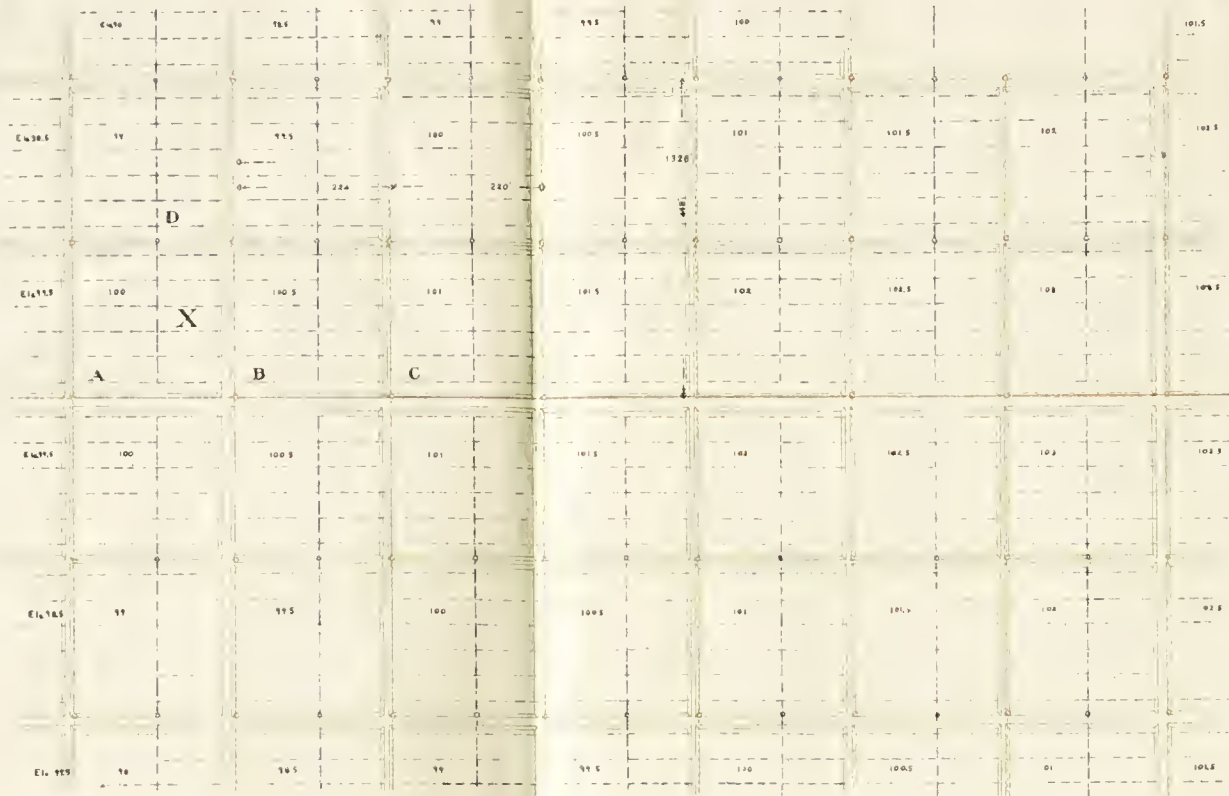
RATE OF RAINFALL IN INCHES PER HOUR



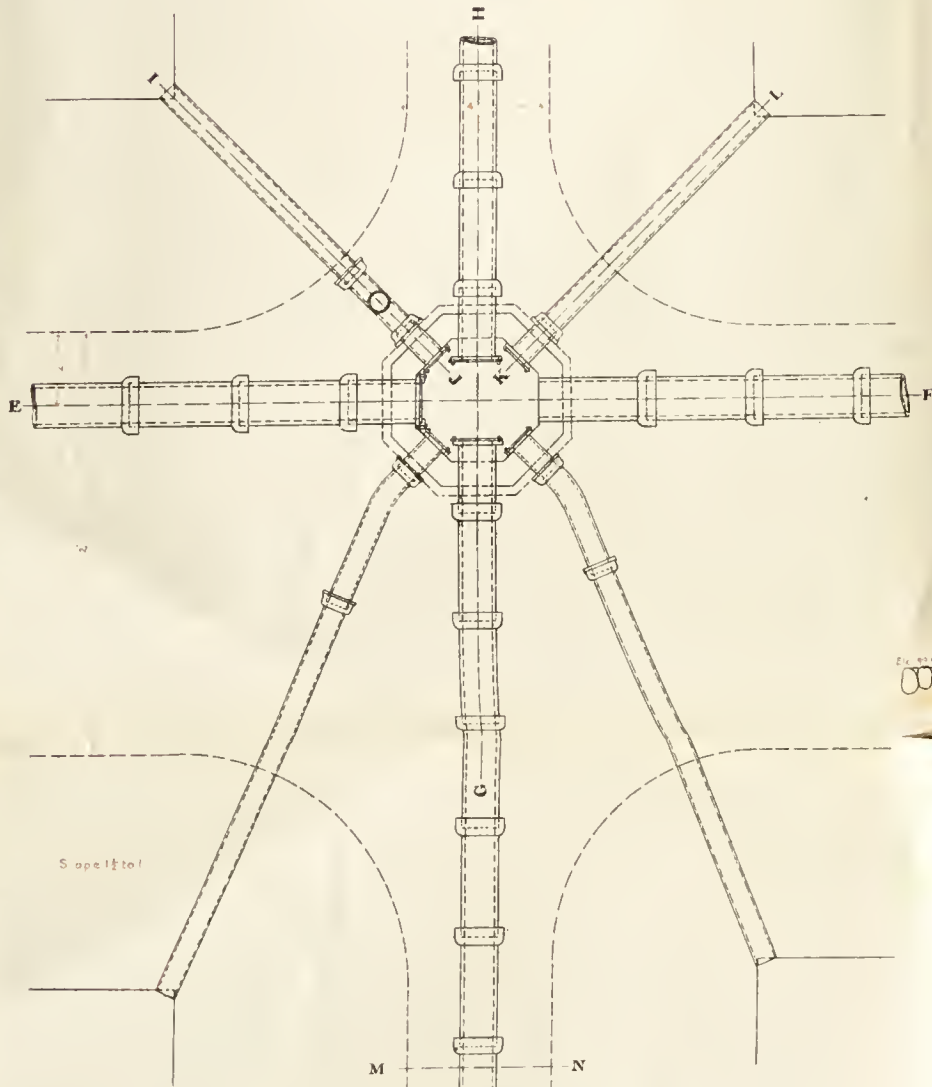
SEWERAGE
COMMISSION { MENDES COHEN.
F.H.HAMBLETON.
E.L.BARTLETT.

NOTE

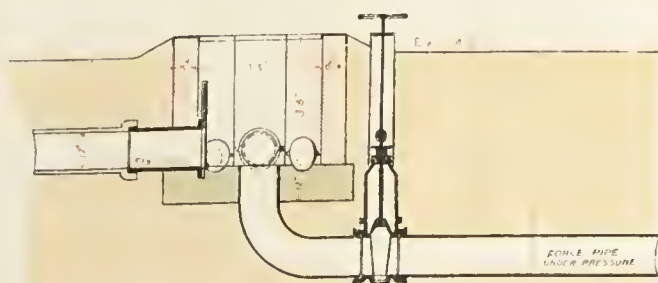
- BANKS AND ROADS
- SUPPLY PIPES UNDER PRESSURE
- VITRIFIED DISTRIBUTION PIPES
- TILES AND VITRIFIED DRAIN PIPES
- MANHOLES
- SAND-SUMPS
- ELEVATIONS ARE ASSUMED



GENERAL PLAN
SCALE 1/3200 FT. TO 1 IN.



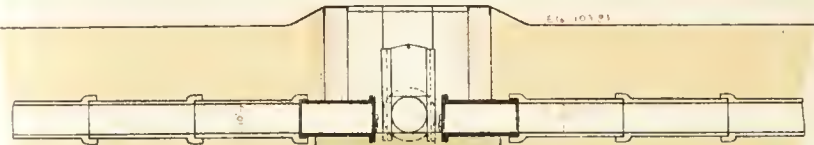
PLAN OF MANHOLE A
SCALE 1/6 FT. TO 1 IN.



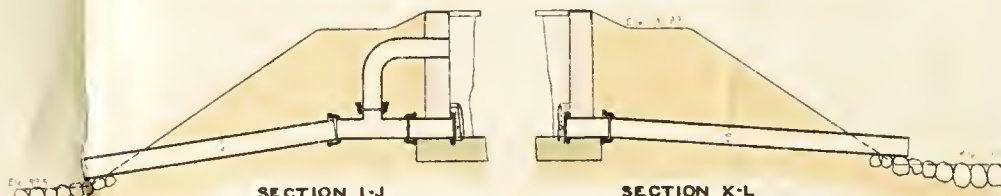
SECTION OF MANHOLE B
SCALE 1/6 FT. TO 1 IN.



SECTION E-F

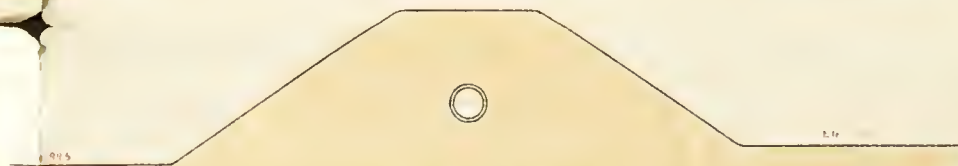


SECTION G-H

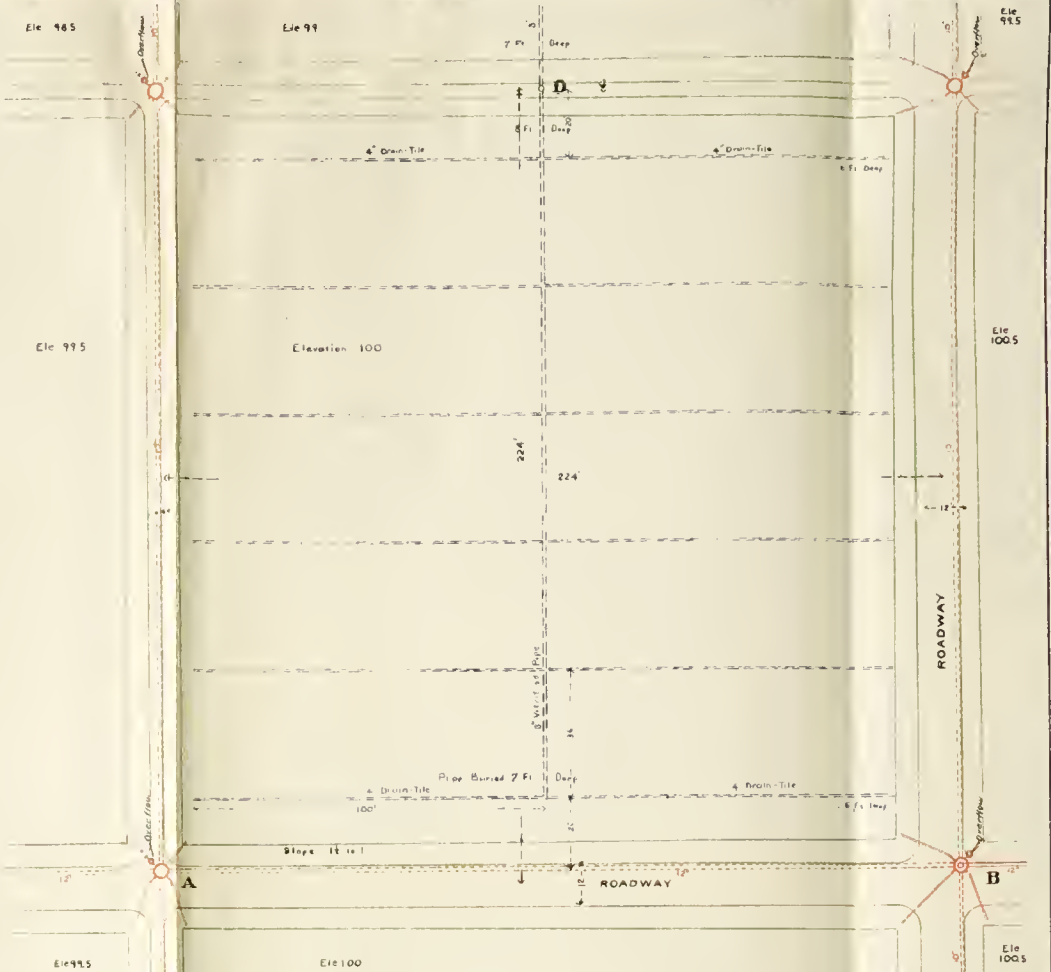


SECTION I-J

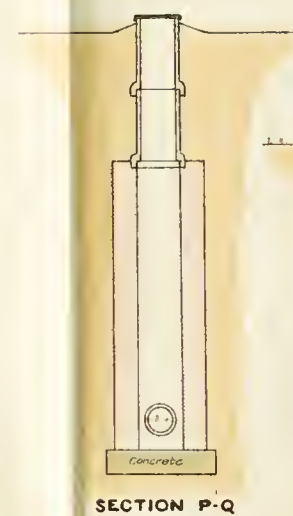
SECTION K-L



SECTION OF BANK M-N



PLAN OF BED X
SCALE 1/60 FT. TO 1 IN.



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URBANA